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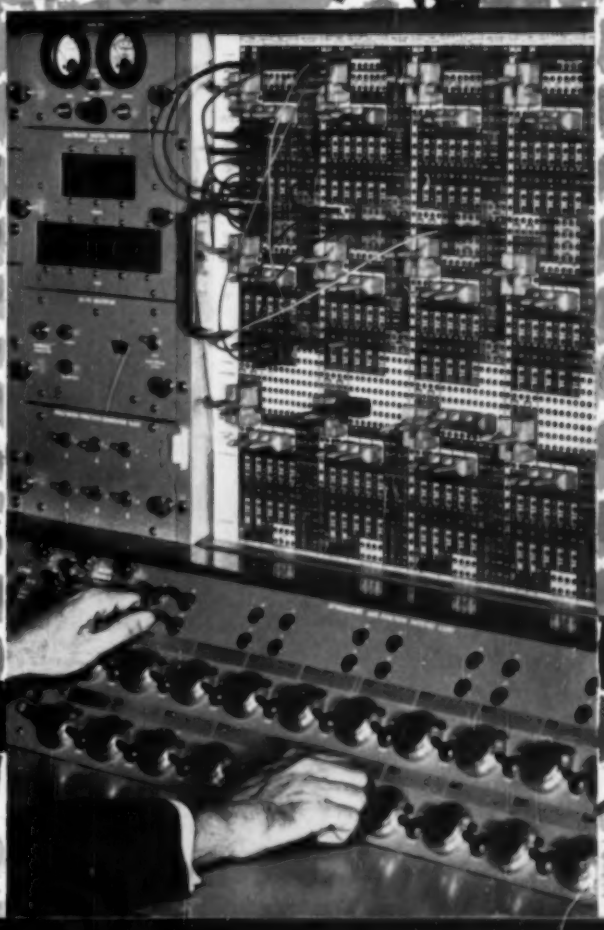

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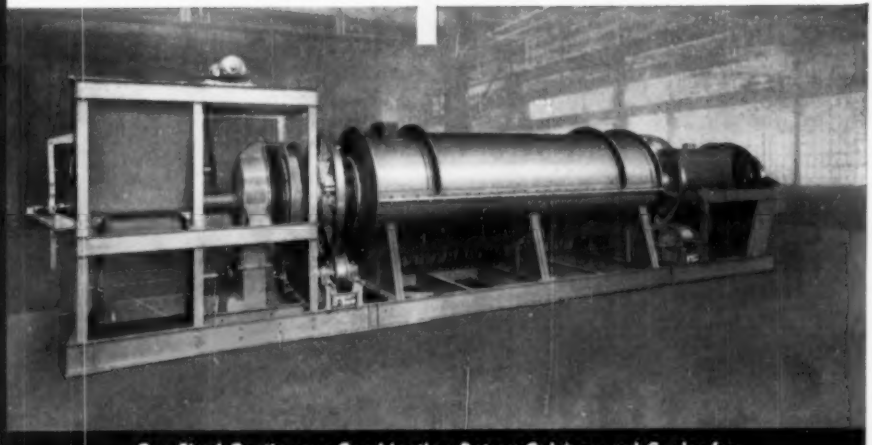

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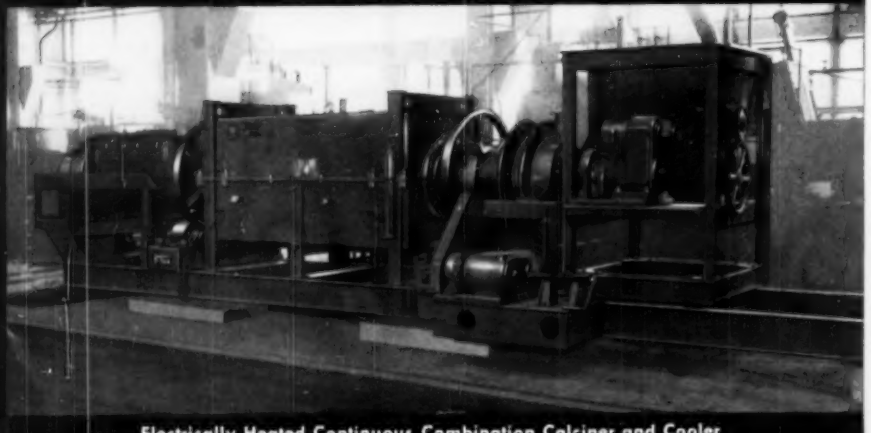

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Cover by Paul Arlt.

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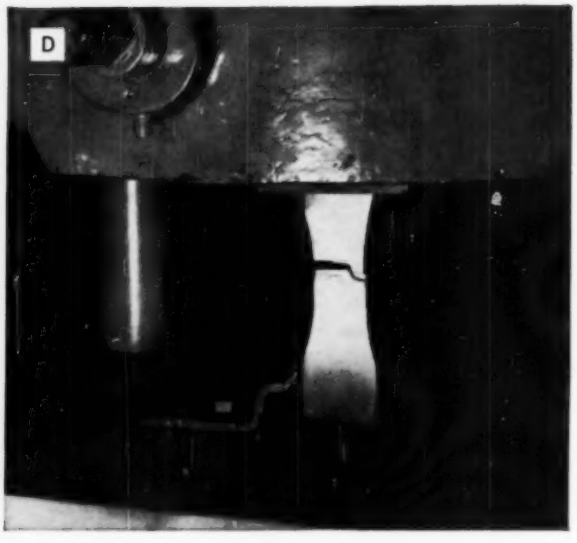

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marginal notes

Petroleum processing spotlighted by new book

PETROLEUM PROCESSING, PRINCIPLES AND APPLICATIONS, R. J. Hengstebeck, McGraw-Hill Book Co., New York, N. Y. (1959), 348 p., $10.

Reviewed by W. A. Cunningham, The University of Texas, Austin, Texas.

The best possible short-phrase description of *Petroleum Processing* is that it is "an abstract on an industry". Ray Hengstebeck has indeed provided an excellent abstract of a multibillion dollar industry covering topics ranging from reaction mechanism and kinetics to such operating problems as fouling of heat exchangers. The book is written in an enticingly concise style which, while it raises more questions than it answers, will give the reader a well-rounded picture of the factors involved in the processing of petroleum. The tenor of the book is expressed properly by its title since it does not confine its presentation to petroleum *refining*.

The author had drawn on his broad experience as a process design engineer and as a lecturer to new technical personnel to provide a short but clear survey of the major (and many of the minor) aspects of a complex industry. The book is not written for the layman seeking a word-picture of petroleum refining, but for the technical man who conscientiously wants to learn more about the practice and basic fundamentals of petroleum processing technology.

The man of long experience undoubtedly will find the information about his specific phase of the industry quite condensed and probably of little value to him. However, he will find mention there of the newest and latest practices, and elsewhere in the book he will read facts about other processing operations and practices of which he probably was not aware. The man new to the industry will find this book both guide and reference which will be of increasing value as he becomes more familiar with processes and techniques.

The extensive list of up-to-date references will be of inestimable value to both the rookie and the veteran. To many it may even be the best feature of the book.

The specific subject matter coverage is, of course, broad and quite complete, ranging from the characteristics of crude oils to such new and potentially useful processes as a clathration. Petrochemical production as such is not included, but since many of the modern petroleum products are really petrochemicals, the data presented are equally applicable to both industries.

This will be a valuable fact and reference book in any library, be it public, industrial or private. The major liability of *Petroleum Processing* is that which is common to most of our modern technical books, namely, the price is too high. The book publishers should take careful note of the increasing cost of books, especially textbooks, since high prices have prevented the adoption of numerous books as texts in college and university courses.

THE PROPERTIES OF GASES AND LIQUIDS, Robert C. Reid and Thomas K. Sherwood, McGraw-Hill Book Co.,

Reviewed by J. W. Riggle, Engineering Research Laboratory, E. I. du Pont de Nemours & Co., Wilmington, Del.

This book consists of eight chapters in which procedures are presented for correlating and estimating the physical properties of gases and liquids. An initial introductory chapter includes explanations of format of the book. Each chapter (with the exception of the introductory chapter) discusses means for correlating and estimating a specific property; for example, Chapter 6 is entirely concerned with viscosity of liquids and gases. The properties included are: critical properties; P-V-T relationships; vapor pressures and latent heats; heats, free energies of formation, and heat capacities; viscosity; thermal conductivity; diffusion coefficients; and vapor-liquid equilibria. An excellent bibliography is also included which contains 480 literature references.

A unique feature of the book is that each chapter is a separate, complete book in itself with a format that is identical to every other chapter with the exception of the introduction. First in each chapter the authors present a brief description of the chapter's content. Then they give a word picture of what the particular property is and describe general methods for measuring it. Next, the correlating or estimating procedures are very clearly presented. Finally, recommendations for the best procedures are presented in order of descending preference. The entire book is liberally

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World-wide influence of American petroleum processing techniques is typified by this refinery built by Kellogg in Iraq.

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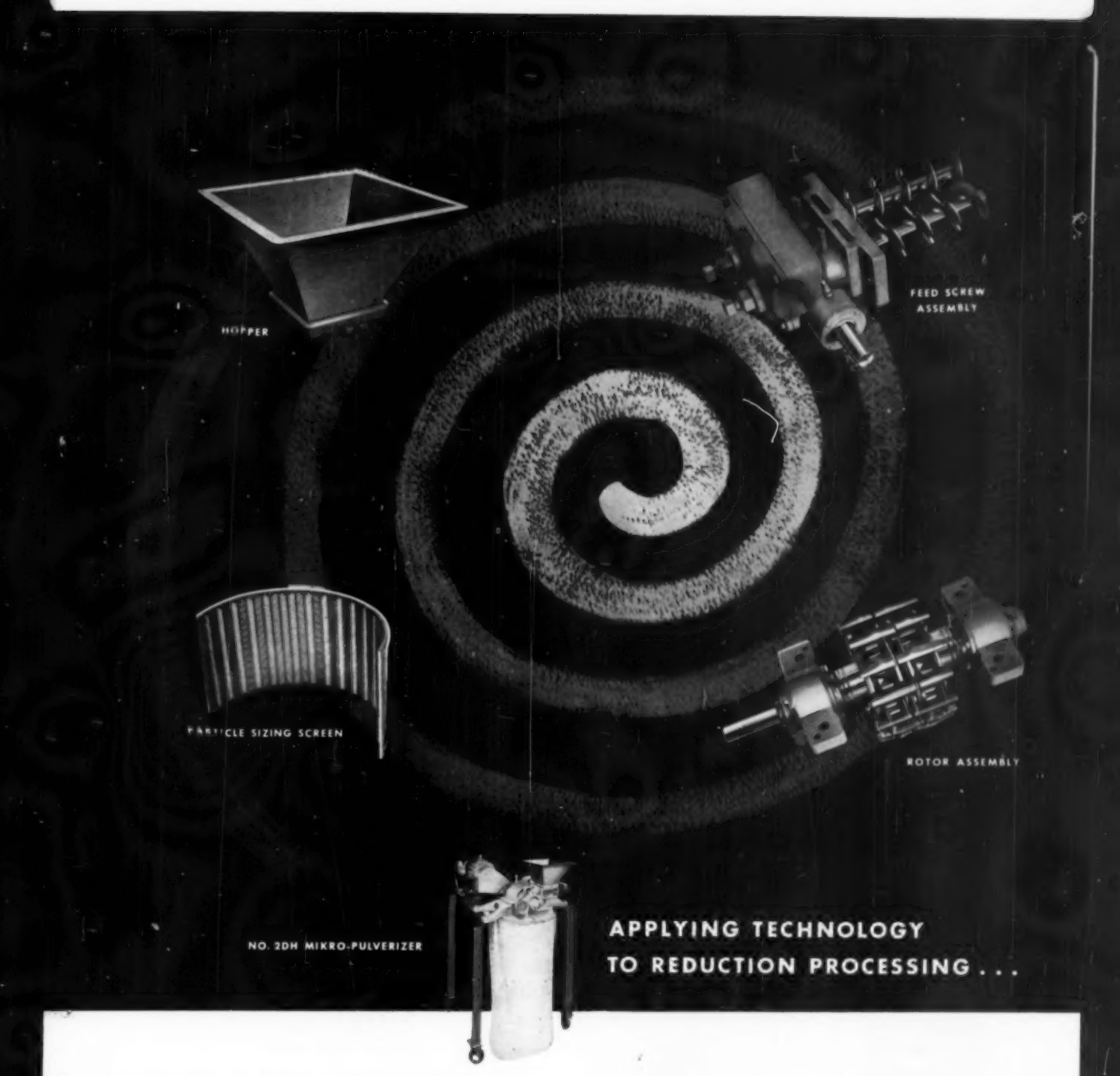

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Marginal notes

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sprinkled with extensive tables containing data for use with each procedure. Tables are also used to clearly show the errors found in the use of the various procedures.

A refreshing and welcome feature of the book is an attempt by the authors to present the reader with a handy "cook book" for getting the end result—a property for use in subsequent calculations. In no case is the reader left in doubt as to what equation to use or how to use it. In fact, where lengthy equations are necessary, the steps for a complete solution are listed with short cuts liberally included to save the engineer-reader time in making calculations. In many cases, thermodynamics are required to understand and use the procedures. The authors have clearly and quickly presented the necessary thermo background in a manner which should be copied by future thermodynamics book writers.

This book contains information of great value for all practicing chemical engineers, but it will have to be continuously revised as new correlation and estimation procedures are presented. It looks like provision should be made now so that when a suitable time has elapsed (five years, perhaps), a second edition will be available. Already several developments have been omitted which should be included in a future edition. For example: (a) more emphasis might be placed on use of computers although slide rule calculations should not be omitted; (b) the whole field of non-Newtonian behavior of fluids should be included in the viscosity chapter, if possible; (c) diffusion in high polymers where the diffusion coefficient varies several fold should be mentioned; (d) total pressure techniques for obtaining vapor-liquid data should be evaluated.

Summing up Reid and Sherwood's book: (a) a gap has been filled in the chemical engineering literature; (b) a different style of technical writing has been used that exactly suits the purpose of the book; (c) a high level of technical excellence is maintained for the engineering world.

LABOR - MANAGEMENT RELATIONS, Charles Wiedemann, Reinhold Publishing Co., New York, N. Y., (1959), 142 p., $3.75.

Reviewed by R. P. Dinsmore, vice president, Goodyear Tire & Rubber Co.

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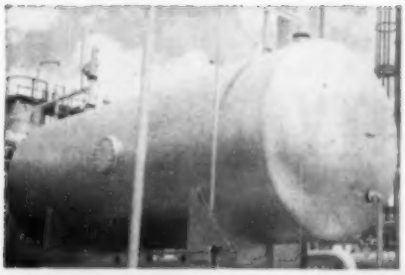

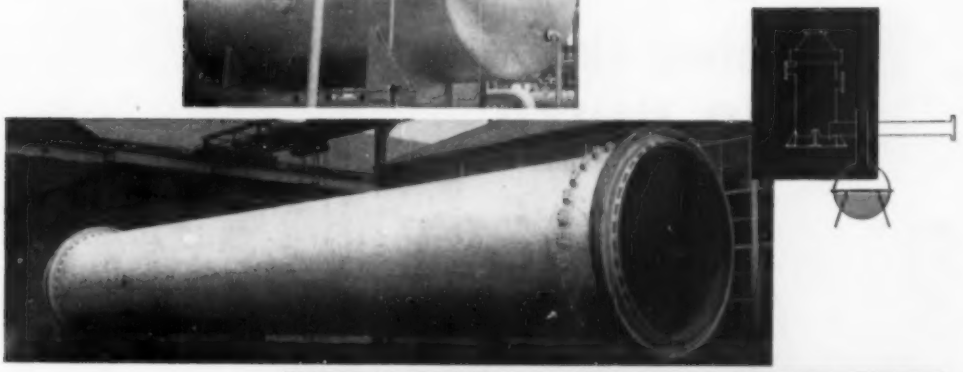

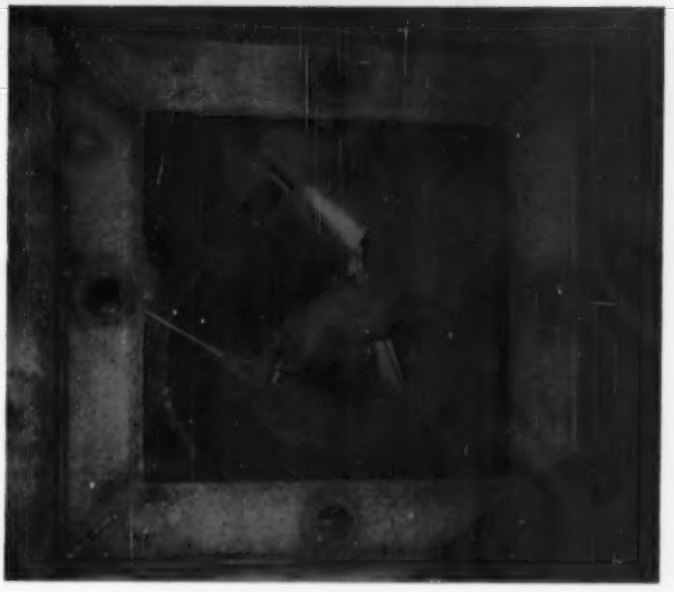

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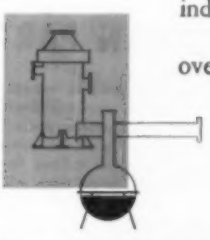

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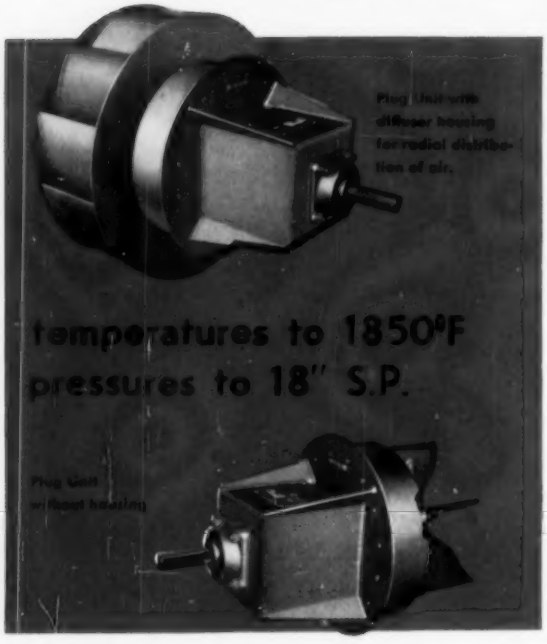

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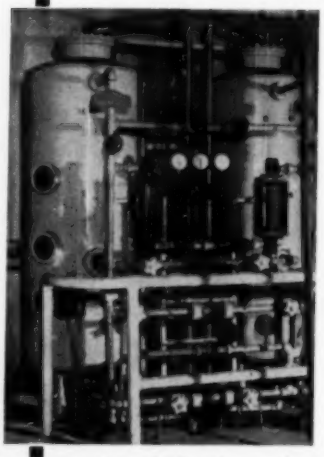

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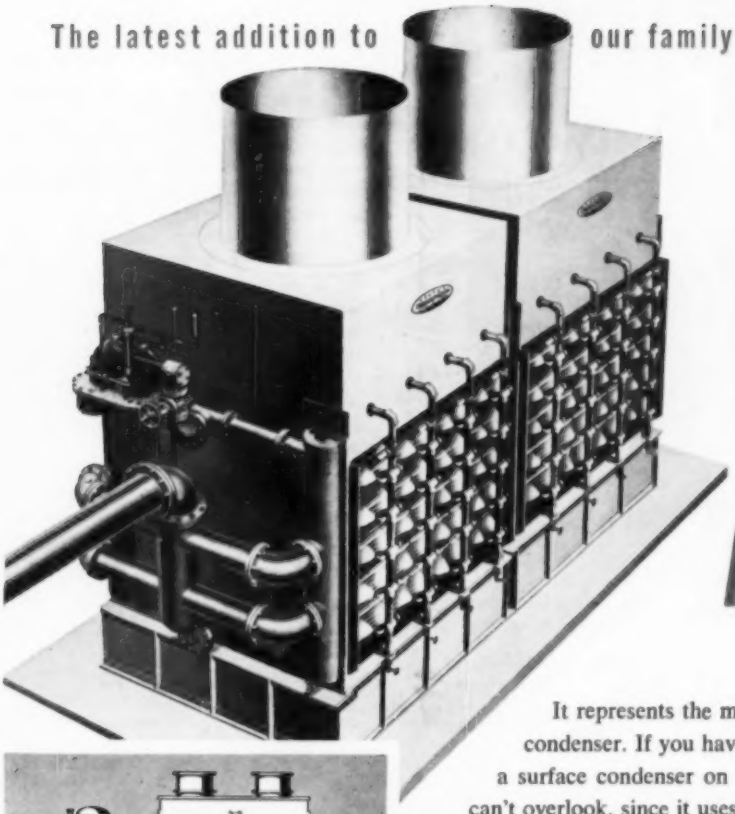

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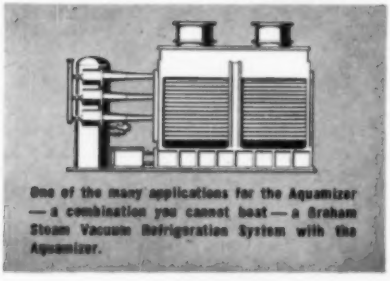

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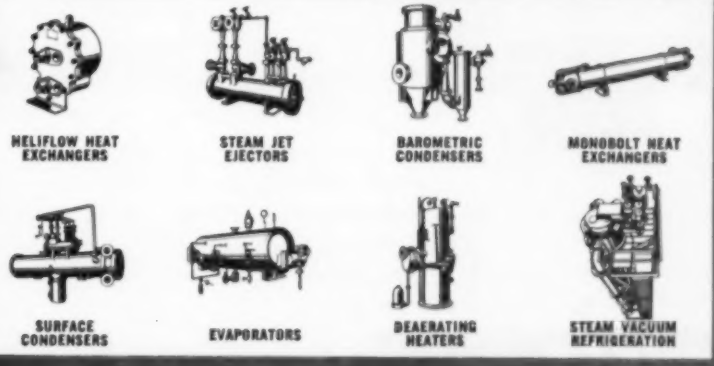

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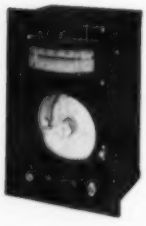
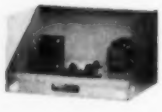
Part of diffusion furnace room, Hoffman Electronics Corporation, El Monte, California. Process is one step in critical manufacture of silicon solar cells.

Gardsman by WEST

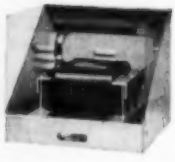
Model JSBG Stepless Program Controllers



Semi-conductors are grown by a highly integrated process, involving time-temperature control. Only the most precise control delivers the required quality, uniformity, efficiency.



Leading producers of semi-conductors find best results from the market's most compact, integrated Stepless Program Controller: by West. This unit infinitely modulates heater power *and* coordinates time-and-temperature control for even the most unstable systems.



Also available: models combining Gardsman off-on, proportioning or 3-position controllers with programming. All are *tubeless* and noted for minimum maintenance and operating requirements. Ask your West representative or write for Bulletin JSB and JG.

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Marginal notes

from page 8

This is an excellent factual presentation of problems which arise in the negotiation and administration of union contracts. It is concisely written in simple language, using an interesting and readable style.

The approach is objective. The foundation for labor contracts is laid by a discussion of the nature of industrial relations and the basis in our laws for union representation. The brief treatment of management dealings with the white-collar employee and the professional employee are symptomatic of the sound, commonsense viewpoint of the author.

Throughout he makes practical suggestions for meeting conditions which experience has shown to frequently occur.

This is a valuable book for those who wish to know the pitfalls of labor negotiations and contract administration without making labor relations a career.

It should especially appeal to the professional man and can be read carefully in one evening.

WORK MEASUREMENT, Virgil H. Rotroff, Reinhold Publishing Corp., New York, N. Y., (1959), 203 p., $4.85. This book presents the fundamental principles and techniques of work measurement and gives examples of application largely drawn from the mechanical industries. It is a systematic presentation of the methods and procedures which have been evolved from time study techniques during the past few decades. It is aimed especially at the objectives of the industrial engineer which involve development of work standards and installing wage incentive programs.

This field is becoming of increasing interest to engineers employed in the process industries where automatic controls take over a large part of the physical work formerly performed by direct operating labor. However, since it deals very generally with these problems as applied to the design and operation of chemical processes, this book will probably be of limited value to most chemical engineers.

FUNDAMENTALS OF PHYSICAL CHEMISTRY, H. D. Crockford, and Samuel B. Knight, John Wiley & Sons, Inc., New York, N. Y. (1959), 463 p., $6.95.

CONTINUOUS ANALYSIS OF CHEMICAL PROCESS SYSTEMS, Sidney Siggia, John Wiley & Sons, Inc., New York, N. Y. (1959), 381 p., $8.50.

For more information, circle No. 22

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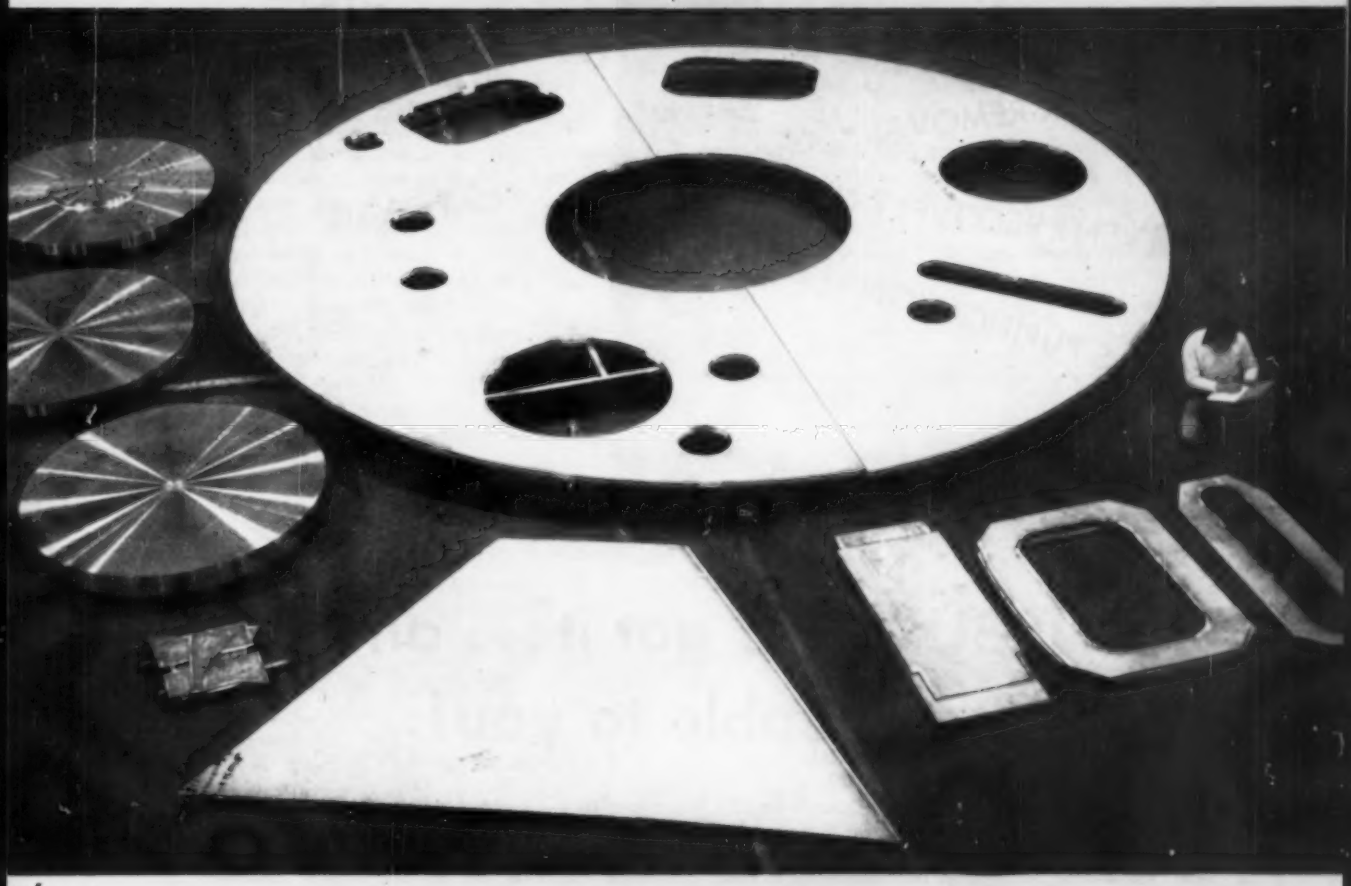

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Chemical industry profits on way back up

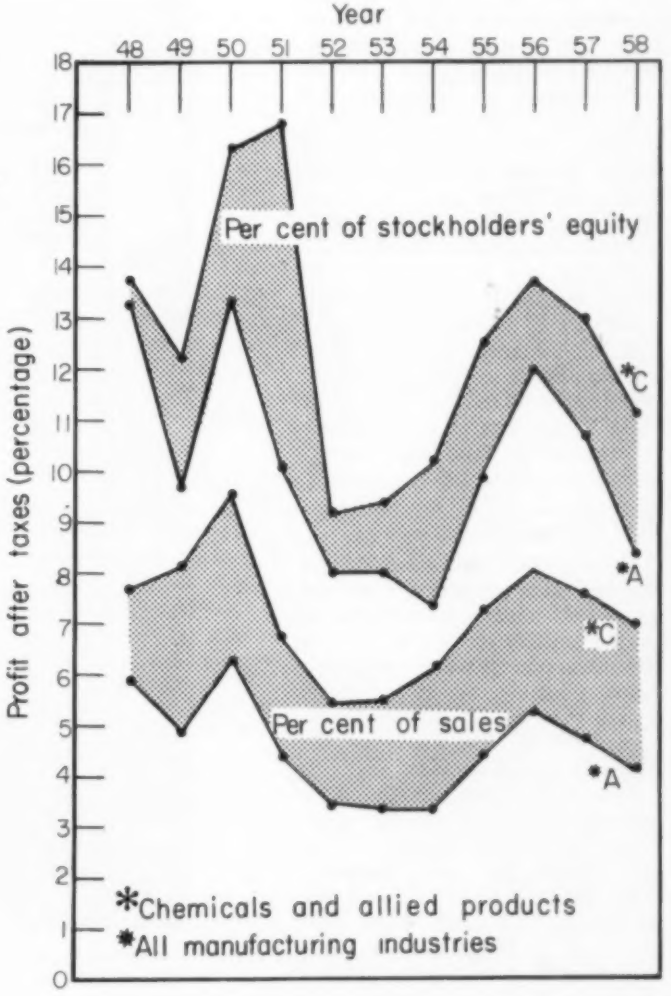
Nine-month interim figures for 1959 substantiate significant recovery for the chemical and allied industries in the past year.

NET PROFIT AFTER taxes in the chemical industry, still on the toboggan at the end of 1958, headed upward again in 1959. However, expressed either as percent of sales or of stockholders' equity, the profit figures show dramatically that the chemical and allied industries have been, and continue, in a stronger profit position than the average of all manufacturing industries.

Statistics compiled by the American Paper and Pulp Association on the basis of reports from the Bureau of Internal Revenue, the Federal Trade Commission, and the S.E.C. (Figure 1), nevertheless point up a definite long-term downward trend in net profits. Even in the good old days of 1956-57, profit margins did not scale the towering peaks of the 1950-51 boom.

At the end of 1958, net profit after taxes for the chemical and allied industries averaged 7.0% of sales, compared to a figure of only 4.2% for all manufacturing industries. Calculated as percent of stockholders' equity, the 1958 profit after taxes averaged 11.1% for chemical and allied industries against 8.4% for all industries. Only industry which exceeded the profit margin of the chemical in 1958 was the tobacco industry, which chalked up a respectable 13.1% net profit after taxes, calculated as percent of stockholders' equity.

Final figures for 1959 will not be available until the annual reports are published. However, interim figures* for the first nine months of 1959 show that profits after taxes as percent of sales averaged 9.2% for fifteen of the largest chemical companies, contrasted with 7.0% for the comparable period of 1958. On the same basis, the average for fifteen leading pharmaceutical companies went up less than 1%—from 12.8% in 1958 to 13.0% in 1959. Obvious conclusion: the drug manufacturers suffered hardly at all from the 1957-58 recession—sickness takes no holiday.


Year
48 49 50 51 52 53 54 55 56 57 58
Profit after taxes (percentage)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Per cent of stockholders' equity
*C
*A
*C
Per cent of sales
*A
*Chemicals and allied products
*All manufacturing industries

Statistics kindly furnished by Smith, Barney & Co., stock brokers.

Plastics push paced by polyethylene film

Billion-pound-per-year club no longer exclusive—vinyls in, polystyrene waiting in the wings and about to come in.

PRODUCTION OF polyethylene film showed a net increase in 1959 of more than 75 million pounds per year, according to a year-end roundup report by Union Carbide Plastics. The plastics industry as a whole, reports Carbide, showed production gains of about 20% over 1958, and a total production of about 5.4 billion pounds.

Polyethylene production for the year totaled about 1.15 billion pounds, a 33% increase over the 865 million pounds recorded in 1958. Production figures for 1960 should total about 1.375 billion pounds, say Carbide's market researchers.

High-density polyethylene continues to show a sharp growth curve. From 8 million pounds in 1957, high-density sales grew to 42 million pounds in 1958, and to approximately 85 million pounds in 1959. Penetration of new markets is expected to raise sales to 135 million pounds in 1960.

Epoxies lagging

"Epoxy sales have not grown as fast as some industry observers predicted," remarks the Carbide report. The 1959 production total of 52 million pounds was considerably below available capacity, although higher than the 41 million pounds turned out in 1958. Prediction for 1960—64 million pounds.

Vinyls have moved into the exclusive billion-pounds-per-year club, with a production total of 1.05 billion pounds per year, compared with 869 million in 1958 and 887 million in 1957. Outlook for 1960 is around 1.2 billion pounds. Influential factor in vinyl expansion has been use of vinyl dispersion resins for coatings, particularly for precoating of metals prior to forming.

Phenolics also fared well in 1959. Total output was about 564 million pounds, a substantial gain over the 488 million pounds turned out in 1958. Polystyrene, too, registered sharp gains, up from 763 million pounds in 1958 to about 900 million in 1959, is expected to pass the billion pound marker in 1960.

PRODUCTION FIGURES (in millions of pounds)

Plastics	1957	1958	1959 (est.)	1960 (est.)
Polyethylene	708	865	1,150	1,375
Vinyl	877	869	1,050	1,200
Polystyrene	680	763	900	1,050
Phenolic	532	488	564	600
Epoxy	29	41	52	64
Cellulosics	148	141	150	160
Urea-Melamine	349	349	370	390
Coumarone-Indene	286	268	256	270
Polyesters	96	117	150	170
Surface coating resins, i.e. alkyds, phthalic, rosin esthers, etc.	584	562	590	610
Miscellaneous*	197	195	250	360
Total	4,496	4,658	5,482	6,249

*Includes acrylic, polyamide, acetal, and polypropylene, etc.

Plastics box score. Actual production figures for 1957 and 1958 (Tariff Commission figures) together with estimates for production in 1959 and 1960 (from Market Research Department, Union Carbide Plastics Company).

Computer combing chemical patents

Machine patent searching technique expected to cut man-hours, turn up new leads for research.

The polymer chemical field, one of the broadest and most difficult areas of patent research, has been singled out by the U.S. Patent Office for its experiment with a new streamlined computer system. This method of patent searching would accomplish in half an hour a job that now takes a skilled researcher nearly a full day, and might be adapted to most patent searching throughout the chemical field.

A government industry research team, formed by the Office of Research and Development at the Patent Office and the Research Division, Textile Fibers Department, of Du Pont, adapted for the first time the agency's punched-card file, which heretofore could be processed only on specially-built equipment, to commercially available data-processing equipment. A Bendix-G-15 digital computer successfully tested the use of a general purpose computer to search for patent information by a serial scanning technique.

The new electronic search system will be a looked-for boon to the chemical industry, since it can turn up areas of invention that have been overlooked. While searching for patented compounds that can do a particular job, the computer can also be instructed to indicate those with similar characteristics that might also perform the same job.

At present, leading chemical companies tend to mistrust a computer for use in an infringement search. However, a patentability search holds greater interest, since the list of alternate materials identified by the computers might be cheaper for manufacturing the product. The searcher can also better evaluate the patentability of his own developments.

Since new discoveries are constantly being made in the polymer field, it would be important if the great duplication of effort encountered in hand-searching methods could be eliminated by an automated searching system. The problem of keeping up with the rapidly growing number of patents obtained each year in the field continues to plague the Patent Office. If this can be overcome in the most difficult area, polymers, perhaps the bottleneck on new products and processes caused by time-consuming patent searches can be ended.

Coming soon—petrochemical and refining exposition

The Chemical Engineer's role in design and development of petroleum and petrochemical production facilities will be the keynote of a Petrochemical and Refining Exposition to be sponsored by the American Institute of Chemical Engineers. Occasion will be the National A.I.Ch.E. Meeting to be held in New Orleans, February 26-March 1, 1961. The exposition will be held in conjunction with several days of technical sessions on chemical engineering in the production and processing of petroleum and petrochemical products. Both the exposition and the petroleum symposia will emphasize the rapidly expanding inter-dependence of these industries and the chemical engineering profession.

Titanium anodes for chlorine production?

Permanent platinum-coated titanium anodes may soon replace the standard graphite anode in chlorine production, according to a year-end survey by Titanium Metals Corp. Tests completed to date are said to indicate that such platinized anodes would almost eliminate down-time caused by anode wear.

Engineer demand up in 1959

Industrial recruiting and overall demand for engineers in 1959 increased materially over 1958, according to a recent survey conducted by the Engineering Manpower Commission of EJC. Net increase in number of engineers hired by industry in 1959 was more than double that in 1958, would have been higher, says EJC, had a sufficient supply been available. The future?—"Demand for engineering graduates is expected to increase further in 1960 and to continue to accelerate in the years immediately ahead." Survey participants projected 1966 needs as 15 graduates for every 10 recruited in 1959. Incongruous note— U.S. Office of Education announces that freshman engineering enrollment has dropped for the second consecutive year, over 3% in 1959, after an 11% drop in 1958.

MATHESON

Compressed Gas Notes

Gas Sterilization with Ethylene Oxide Mixtures

The science of sterilization has been changing over the past few years. Gone is the necessity of lengthy exposures to high heat to insure effective sterilization.

Heat and moisture-sensitive items, often ruined by long exposures to steam, can now be effectively and completely sterilized by the turn of a valve. The valve is on a cylinder of sterilizing gas called by different proprietary names, but consisting of Ethylene Oxide plus an inerting non-toxic, non-flammable gas to render the total mixture either non, or less flammable. For most sterilizing purposes, Ethylene Oxide concentrations of 450 to 1000 milligrams per liter of chamber space will be sufficient to provide a 100% kill.

Mixtures

The sterilizing mixture can be compounded in a number of ways to render the mixture more or less concentrated in Ethylene Oxide, or to have higher or lower cylinder pressure to suit the needs of the sterilizer function and design. The Matheson Compressed Gas Catalog lists sterilizing gas mixtures available from stock from all 3 Matheson plants. Special mixtures of any concentration of Ethylene Oxide are available from Matheson.

Fig. 1 illustrates the type of cylinder used to package sterilizing gas mixtures. The picture represents the sterilizing gas in two phases—liquid and gas. An eductor tube extends into the liquid phase of the mixture. When the cylinder valve is opened, the vapor pressure of the mixture forces the liquid out of the cylinder, through the eductor tube and valve. From there, the mixture may be piped directly to a sterilizer where the mixture will vaporize and do its job. Another method of dispensing the mixture to a sterilizer, is by first discharging the liquid into an expansion tank where it is allowed to completely vaporize. The mixture is then automatically fed from the expansion tank to the sterilizer as a completely mixed and vaporized gas, insuring a homogeneous mixture throughout the sterilizer.

Advantages

Here are some of the advantages gained by the use of gas sterilization:
Rapid action. All forms of organisms destroyed at ordinary temperatures. All types of substances and many packaging materials can be penetrated, allowing completely packaged items to be sterilized. (Even the pages of a closed book can be effectively sterilized.) Low toxicity to humans and animals. Can be rendered non-flammable. Convenient to handle. Easy storage. Gas completely removed by aeration; no residue. Non-corrosive.

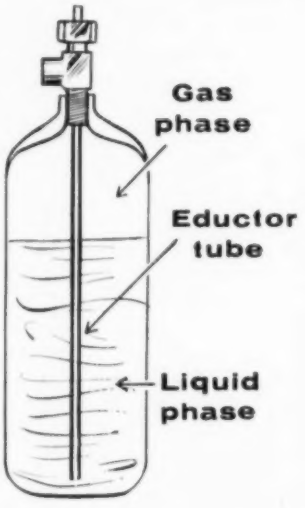


Fig. 1

Typical Applications

Here are a few of the items that have been effectively sterilized with sterilizing gas containing Ethylene Oxide: Plastic bandages, polyethylene bottles, packaged catheters, penicillin, surgical sutures, blankets, leather, wool, cotton, nylon, paper, plastics, foodstuffs, glassware, airplane cabins, railroad cars and buses.

We are equipped to supply sterilizing gases in regular or special formulations, in a variety of cylinder sizes. Our Sales Engineering Department will be glad to furnish further details and quotations concerning your needs. We will welcome your inquiries on gas sterilization.

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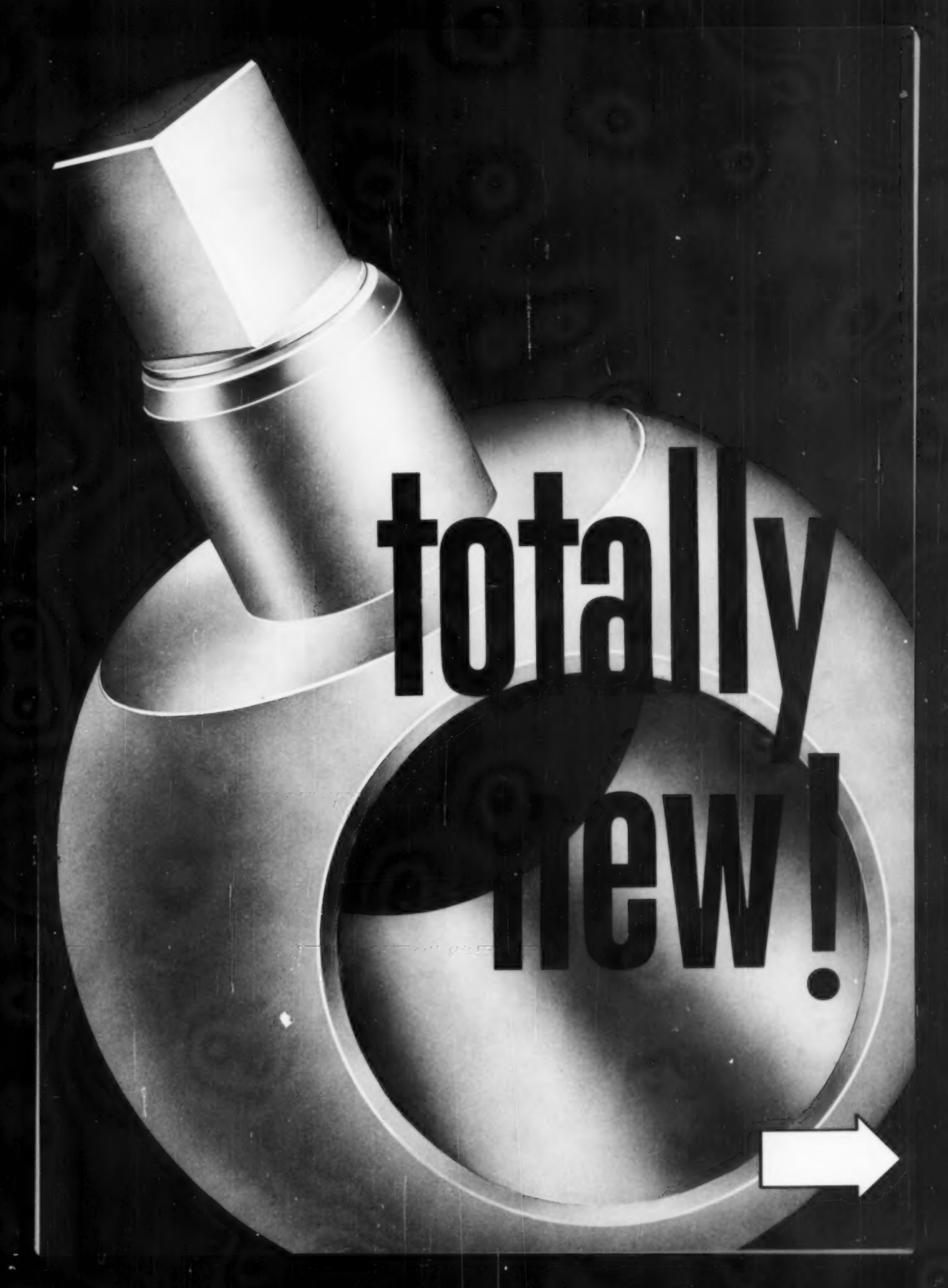
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ORDINARY BALL VALVE

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Floating ball puts excessive pressure load on fixed seats. Results in distortion and short life.

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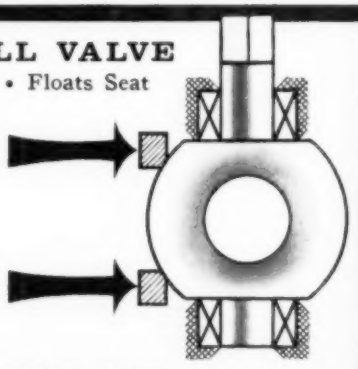
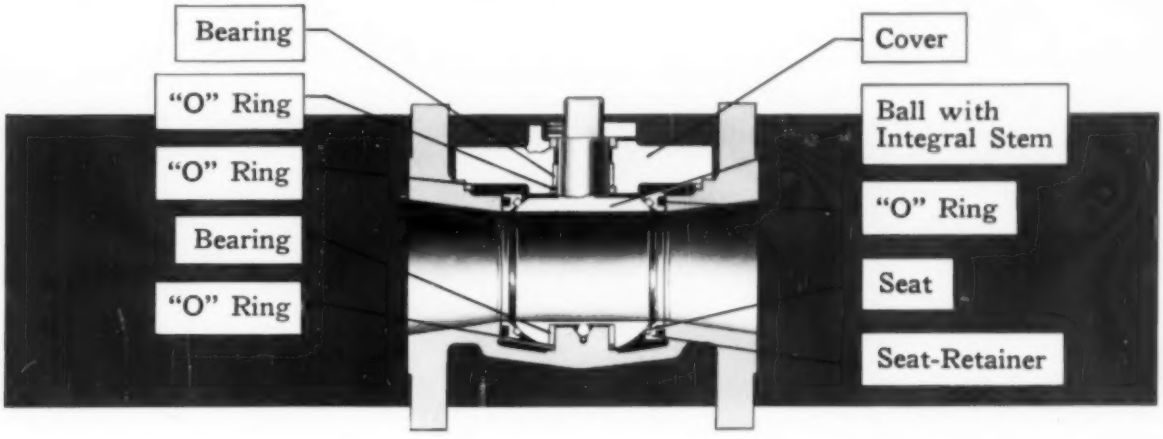
Fixes Ball • Floats Seat



FLO·BALL bearings absorb all pressure forces. Elimination of excessive seat loading insures long life.

The Series 711 ***FLO·BALL*** valves are available for off-the-shelf delivery. All are manufactured to standard ASA dimensions in semi-steel, carbon steel, 316 stainless steel, and aluminum (ASTM 356-T-6) for body and ball, Teflon for seats, and Buna "N" O-Ring seals. Other materials are also available. These valves operate at pressures to 300 psi, temperatures to 400° F.



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letters to the editor

Chlorination of Ilmenite–author answers critic

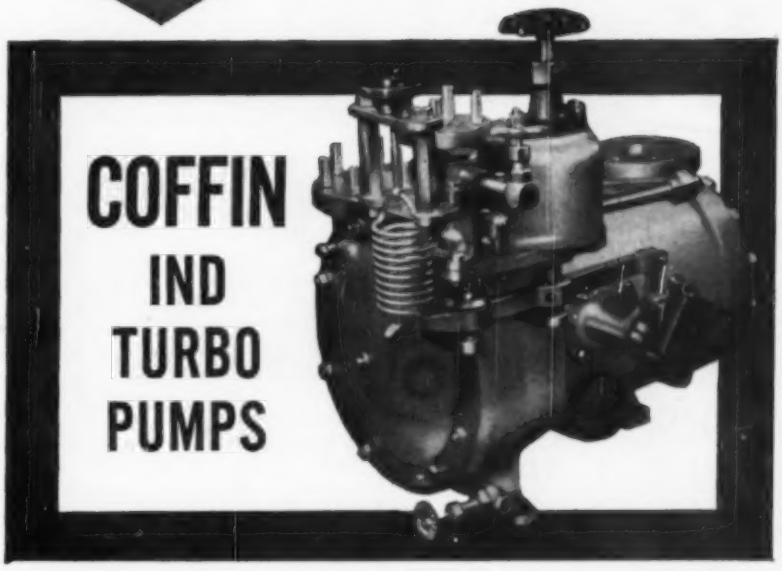
I was interested to note the article entitled, "Chlorination of Ilmenite in a Fluidized Bed," published in the October 1959 *CEP*. I have several comments to make in connection with the article.

(1) The authors concluded that the chlorination reaction is not affected significantly by mass transfer at 750°C when the linear gas velocity in the tube is greater than 25 ft. per minute. They then go on to make the statement that at higher temperatures the mass transfer effects become even less important because the linear gas velocity increases for the same mass velocity as the temperature is increased, due to the decrease in gas density. The rate of mass transfer may be expected to increase by about 0.8 power of the linear velocity and therefore of the temperature also. However, the rate of chemical reaction can be expected to increase much more rapidly with temperature – exponentially according to an Arrhenius type equation. Therefore, one might expect that the mass transfer effect would become increasingly important as the temperature increases and the ratio of the rate of mass transfer to the rate of chemical reaction decreases. Perhaps this effect causes the apparent change of mechanism at 750°C noted by the author and shown in Figure 3.

(2) I agree with the observation that W/F in the rate expression varies with conversion. However, the assumption made by the authors that W in this expression is directly proportional to the weight of iron oxide in the bed is open to question. The authors point out that the part of the iron present as FeO is chlorinated at a much faster rate than the Fe_2O_3. Also, the iron oxides in the ilmenite exist as an integral part of the mineral's crystal structure and not as discreet particles. The ilmenite particles are porous in structure. In the light of these points, as temperature increases and mass transfer becomes more important, I would expect that the rate of chlorination

continued on page 28

Complete Pump, Turbine and Controls



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Air pollution and lung cancer

THE AIRBORNE EFFLUENT from industrial plants must now share with cigarette smoke and automobile exhaust the spotlight of suspicion in the search for the source of cancer causing chemicals.

A third of a century ago, lung cancer was an inconsequential problem. But today it is killing people at the rate of about 35,000 a year, and it's incidence is increasing at a rate greater than that of any other disease. Statisticians have been quick to correlate a corresponding increase in the use of cigarettes and automobiles over the same period of time. But it has been only since the recent identification of specific airborne chemicals known to be present in the products of incomplete combustion of fuels that airborne industrial effluents have begun to attract official attention. Richard A. Prindle, Chief, Air Pollution Medical Program, U. S. Department of Health, told a recent Conference "A word about the mode of action of air pollution in carcinogenesis. . . . . true carcinogens do exist in the air, and many of these result from almost any type of incomplete combustion of almost any product. They include identified compounds such as 3, 4 benzpyrene, and more recently, 3, 4 benzfluoranthrene. Certain aliphatic hydrocarbons have produced skin cancers on mice after isolation from fractions of the atmosphere, and other substances may act as co-carcinogens."

To back up his statements, Prindle submitted the following table:

Contributing factors to bronchogenic cancer urbanization and smoking.

	Assumed Population[1]	Rate[2]	Deaths
Urban smokers	3,040,000	79.0	2,401
Urban nonsmokers	3,040,000	11.2	340
Rural smokers	3,040,000	65.2	1,981
Rural nonsmokers	3,040,000	1.0	30
			4,750

Notes: (1) Total 1950 population of white males 50 to 69 years of age distributed equally in all areas.

(2) Rates from Hammond & Horn's data, adjusted for city size, except for rural nonsmokers which is an arbitrary minimal.

The identification of specific chemicals as the offending carcinogens will give the technologist the means for prescribing specific treatments.

The compilation of separate data for each locality will give the statistician an opportunity to make more accurate deductions. For example, based upon a national average, we know that in the United States we have half the incidence of lung cancer in rural areas as we have in urban areas, but we also know that the cities with the greatest air pollution have the greatest incidence of lung cancer. It is of great significance to industrialists that government officials know exactly which cities are the greatest offenders and what types of industries are located therein.

By 1955 it had become obvious that the progress being made by voluntary action by industry was insufficient to minimize air pollution. The 84th Congress enacted Public Law 159, known as the Air Pollution Research and Technical Assistance Act. This act as amended by the 86th Congress (Public Law 365) which continues the authorization for up to $5,000,000 a year for cooperative studies until June 30, 1964, is the sole national legislation under which the Department of Health, Education and Welfare fights the air pollution problem. The act does not provide for the exercise of police power by the Federal Government. There is no attempt to impose standards of purity. However, there were fourteen air pollution bills affecting the Department of Health, Education and Welfare introduced during the first session of the 86th Congress.

As the harmful pollutants of urban air become more specifically identified, as their sources become better known, as their effects on human health become more intense (as they will with increasing concentration) such legislation as required to insure safe and healthful urban atmospheres may be expected.

—J. L. Gillman, Jr.

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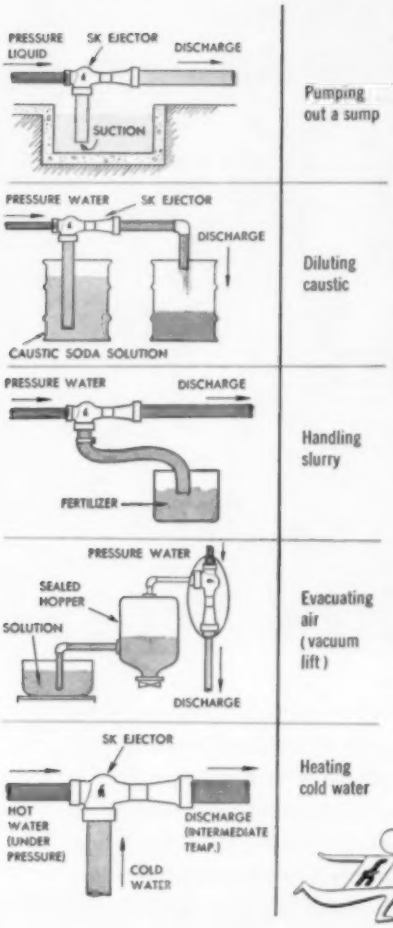

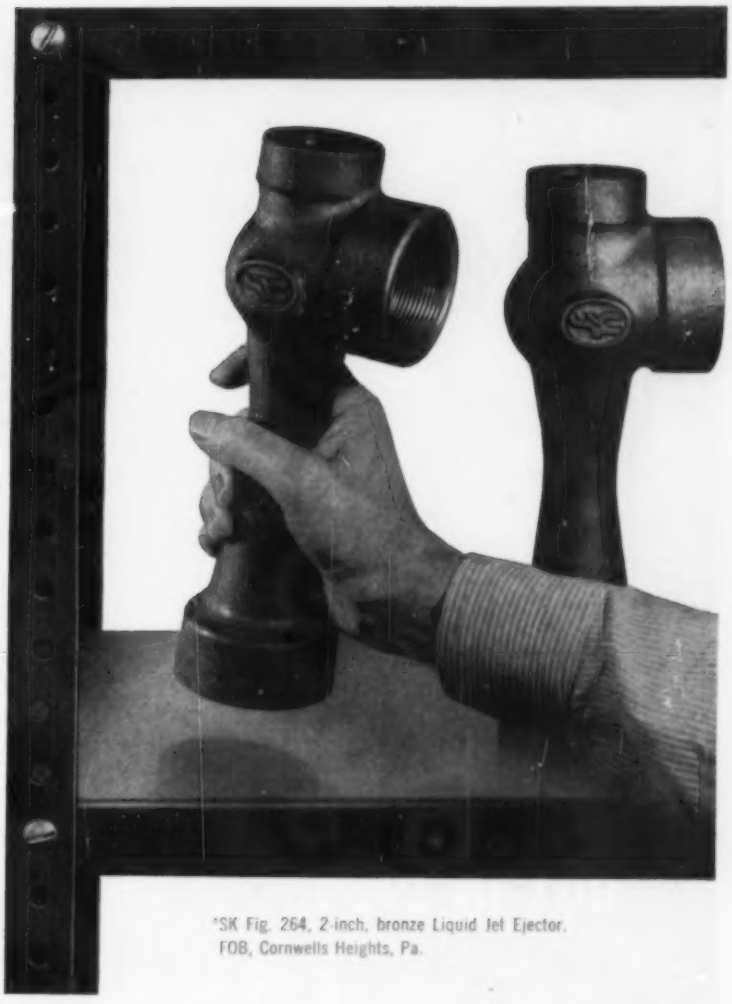

*SK Fig. 264, 2-inch, bronze Liquid Jet Ejector. FOB, Cornwells Heights, Pa.

Want to pump out a sump . . . mix two liquids, or a liquid and a solid . . . handle a slurry . . . prime a pump . . . agitate a solution? Low cost, uncomplicated SK Liquid Jet Ejectors are ideal for *any* of these jobs. That's why thousands of companies (like yours) keep several *always* in stock. Liquid Jet Ejectors utilize the kinetic energy of a pressure liquid to pump, mix and agitate other liquids, handle slurries and fine solids, and evacuate air. They are stocked in cast iron, bronze, 316 stainless steel, PVC, Haveg, and PYREX brand tubing, for quick delivery. The sketches will give you a few ideas on how you might use a stock ejector. For complete details on types, sizes, capacities, write for Bulletin 2M.

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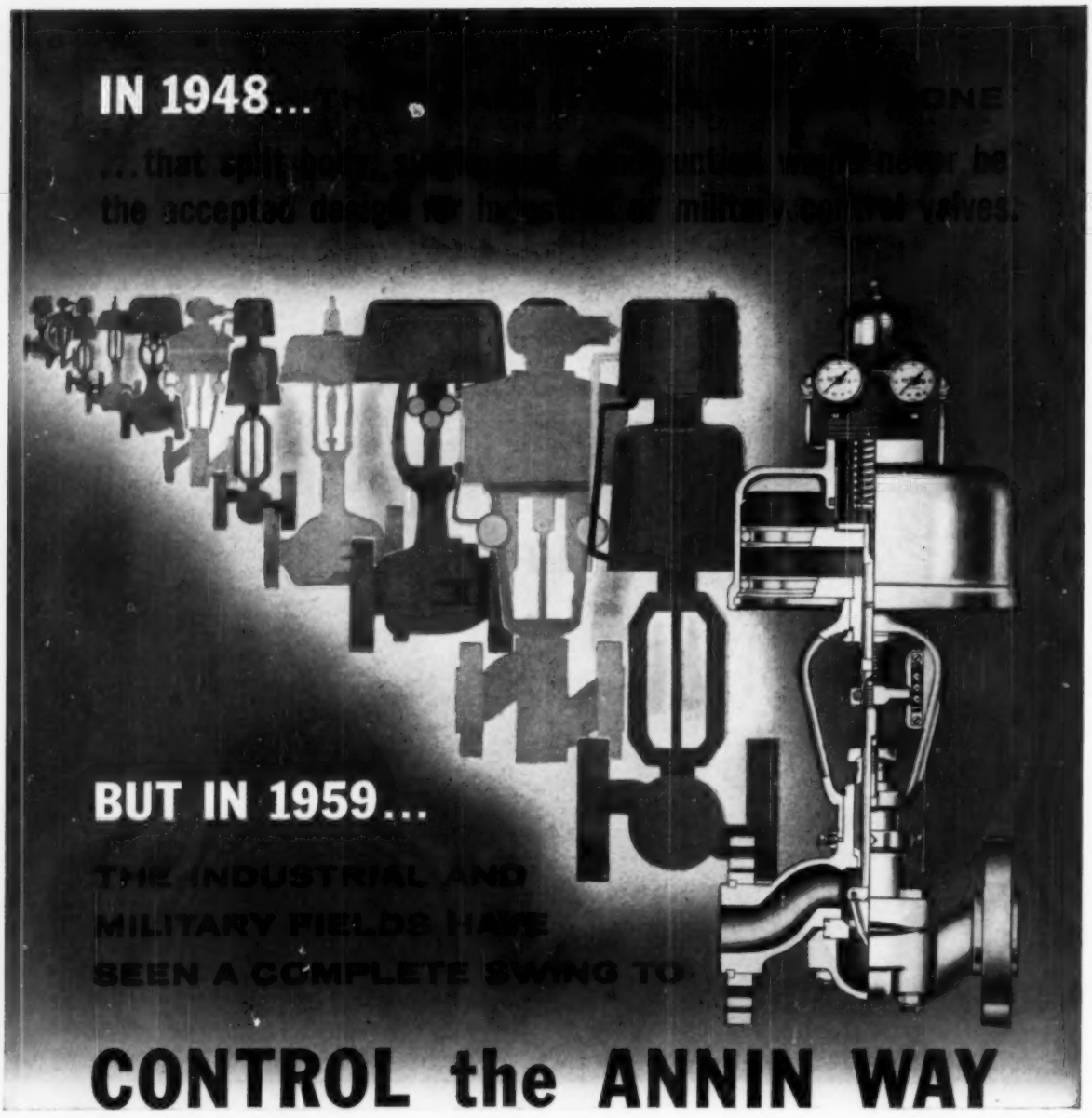

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Letters to the editor

from page 23

per unit weight of iron present in the bed will decrease as conversion increases since the iron remaining in the ore particle is increasingly more difficult for the chlorine to reach. The assumption that W is directly proportional to only the weight of iron oxide in the bed neglects these diffusion effects since it is assumed that all the iron oxide in the ore is equally accessible.

(3) The authors have taken the partial pressures of the reactants in the rate expression to be that of the outlet gas. This tacitly assumes that the flow in the reactor is completely back mixed in the gas phase. Perhaps a better assumption for a tubular reactor is that the gas phase is in plug flow so that the correct partial pressures to be used average of the inlet and outlet in any rate expression are some partial pressures.

I will be interested to learn if the authors have any comments on these points.

M. NADLER

Roselle, N. J.

Ed. note. *Reader Nadler's comments on the article in question were passed on to the authors. Writing for all three authors, author Doraiswamy answers below, point by point.*

1. It is true that the ratio of the mass transfer rate to the chemical reaction rate decreases as the temperature is increased, but we believe that by operating at a sufficiently high feed velocity (25 ft./min at S.T.P.) we have maintained the mass transfer rate at a very high, more or less constant (neglecting for the present the effect of temperature on gas velocity) value at all the temperatures studied; thus the decrease in this ratio is almost entirely due to the expected increase in the chemical reaction rate. That mass transfer would be the controlling step at very high temperatures (or with an extremely active catalyst in the case of catalytic reactions) is obviously true, and this is precisely the reason why we have operated at a high velocity and in a temperature range of 150°C only. Our statement that, at a fixed high inlet velocity, the actual velocity within the reactor increases with increase in temperature was only

continued on page 30

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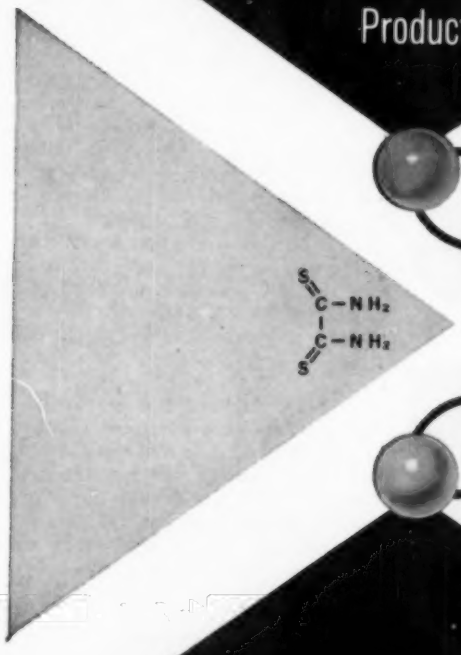

DITHIOOXAMIDE

Mallinckrodt Chemical Works, St. Louis, Missouri, recently announced this new building block...a chemical that can go in many directions to create new and better products. For example, the manufacturer suggests applications for dithiooxamide and its derivatives in the fields of metal sequestrants, pigments, organic intermediates and plant growth regulators.

A new building block with many potentials ...and as with so many such chemicals, Sulphur is a key ingredient!

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Letters to the editor

from page 28

meant to indicate that we were operating at sufficiently high velocities at all the three temperatures. In view of what has been stated above, I cannot agree with Mr. Nadler's view that the change in mechanism at 750°C is due to mass transfer effects. On the other hand, it seems more likely that the change is of a chemical nature, the precise nature of the change being open to speculation.

2. Mr. Nadler's contention that pore diffusion should be taken into account is of course reasonable. Although detailed studies on the effect of particle size were not carried out, we should perhaps have mentioned in our paper the fact that a few preliminary experiments carried out at different particle sizes gave results of a similar nature. Thus any anticipated reduction in chlorination rate as the reaction progresses can, for all practical purposes, be neglected and W taken as being directly proportional to the weight of iron oxides in bed.

3. In a fluidized bed reactor of the type we have used, the reactor is neither fully backmixed nor tubular but would perhaps tend towards the former. Thus, while the use of outlet partial pressures in our rate equation may not be wholly correct, it is perhaps the best that could be done since the postulation of plug flow is, in our opinion, far less acceptable, and introduces a second uncertainty—the kind of partial pressure average to be used.

I hope this will answer Mr. Nadler's comments which have been very welcome.

L. K. Doraiswamy
Institut de Genie Chimique
Toulouse, France

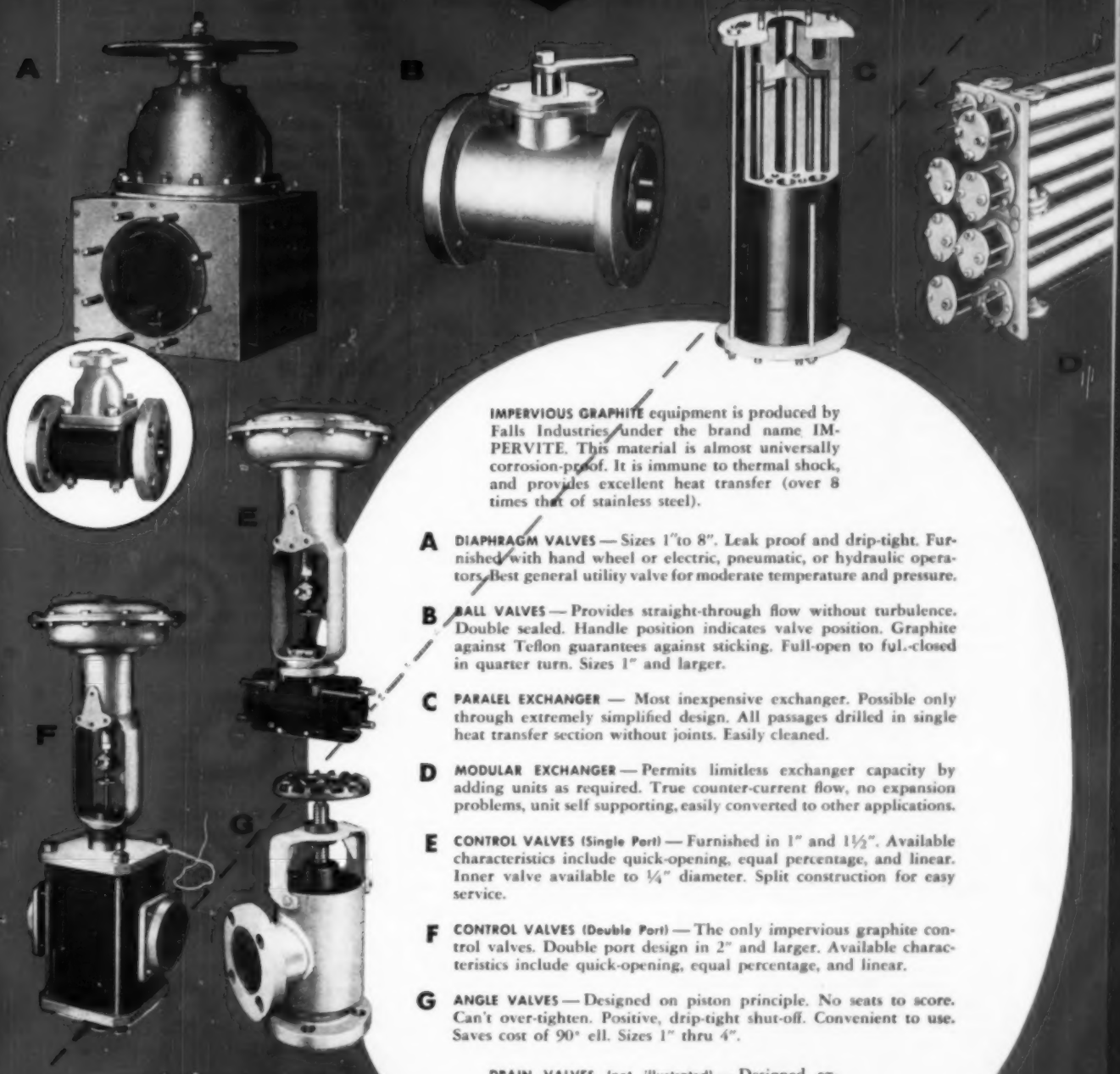
Author of 1958 CEP article now identifies mystery alloy

An article entitled "Urea," of which I was the author, was published in the April, 1958 issue of *Chemical Engineering Progress*. The article

continued on page 32

For more information, circle No. 5

. . . more new impervious graphite equipment from FALLS FI INDUSTRIES



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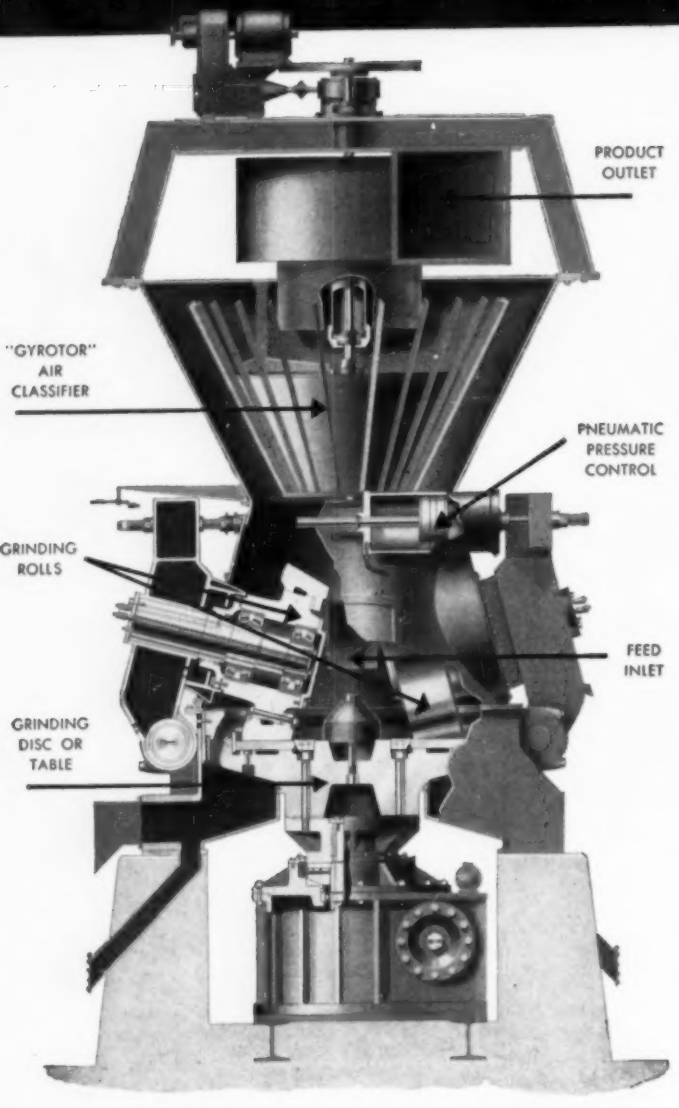
DISC-ROLL MILL



The Hardinge Disc-Roll Mill is applied to dry grinding of minerals such as talc, limestone, coal, phosphate rock, bauxite, clays, celestite, and gypsum.

The Disc-Roll Mill incorporates pneumatic roll-loading. Since the pressure on the rolls can be released or increased at will, complete flexibility of operation results. The problem of over-loading is eliminated. Also, the **Hardinge "Gyrotor" Classifier** is standard equipment on the Disc-Roll Mill. This classifier provides very close control of the finished product over a wide range of sizes. Ask for Bulletin 52-40.

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Letters to the editor

from page 30

contained experimental data relative to the corrosion rates of various materials of construction when exposed to urea synthesis conditions. These data were obtained during the operation of a urea synthesis pilot plant by the Spencer Chemical Company. One of the materials which was listed as having a very good resistance to corrosion was identified as "Alloy Z." At that time, Spencer Chemical Company did not wish to divulge the identity of this material. However, a recent decision by the company enables me to identify "Alloy Z" as type 446 stainless steel.

G. E. CHENOWETH
Spencer Chemical Co.
Pittsburg, Kansas

Chemical process industry featured at New York Section Lecture Series

THE CHEMICAL PROCESS industry is featured in the 1960 Spring Lecture Series of the New York Section. Titled "You, Dollars, and the Chemical Process Industry," the six evening lecture-discussions start March 1 with a basic rundown on "What is the CPI?" Other sessions take in costs and profit accounting, marketing, financing, and governmental influences.

Details of the program are:

What is the CPI, Lewis Lloyd, economist, Dow Chemical.

Planning and Forecasting, R. W. Schramm, general manager, development, Southern Nitrogen.

Costs and Profit Accounting, K. Gutshaw, control manager, Union Carbide Chemicals.

Marketing: Selling and Advertising, B. R. Putnam, manager, Petrochemicals Department, American Cyanamid.

The Governmental Framework, (Patents, anti-trust laws, etc).

Financing the CPI's Future Growth, F. Williams, president, The Chemical Fund, and N. Loud, F. Eberstadt & Company.

Time for the two-hour lectures is 6:45 to 9:00 PM, set to make commuters happy. Location is the Texaco offices of the Chrysler Building, 135 East 42nd Street, New York City. The entire Tuesday night series is $15, with individual lectures at $5 each.

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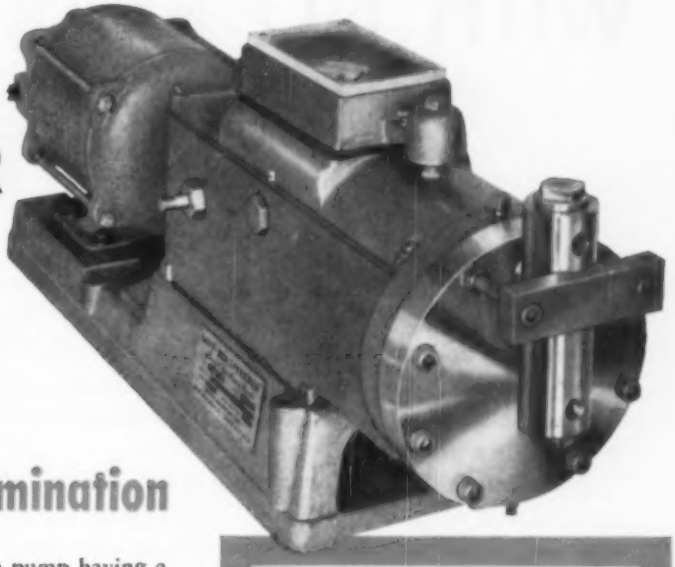

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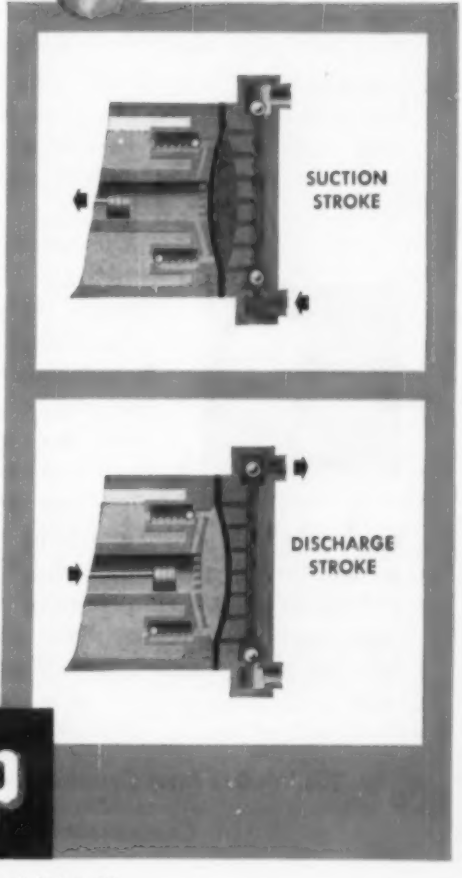
Lapp Pulsafeeder is a piston-diaphragm pump having a hydraulically balanced diaphragm and a closed hydraulic system. Its reciprocating piston action provides accuracy of positive displacement while the diaphragm isolates liquid being pumped from the pump's working parts. Eliminates need for stuffing box or running seal . . . prevents product leakage and contamination. Maintenance costs, too, are reduced to next to nothing. There are practically no repairs or replacement parts.

All Pulsafeeder pump parts contacting liquid are of special corrosion-resistant materials. Pumping speed is constant; variable flow results from variation in piston-stroke length, controlled manually by hand-wheel, or, in auto-pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable. Pulsafeeder capacities range from 585 ML per hour up to 24 gpm maximum flow and pressures from minus atmospheric to 6800 psig.



WRITE FOR BULLETIN 59 containing typical applications, flow charts, description and specifications of models of various capacities and constructions and special leakage chart. Lapp Insulator Co., Inc., Process Equipment Division, 3716 Poplar St., Le Roy, New York.

Lapp

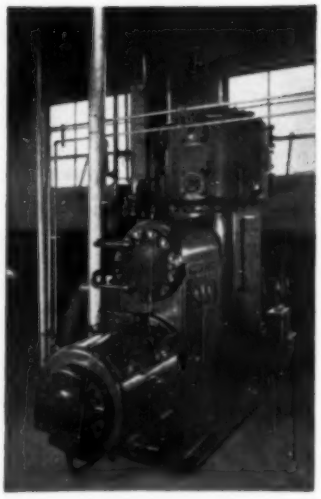
For more information, turn to Data Service card, circle No. 29

60,000 HOURS . . . WITH NO BEARING WEAR

in this IR compressor

Sound unbelievable? Here's how it happened.

This 125-hp Ingersoll-Rand XLE compressor was installed in 1950 at the Standard Products Company in Cleveland. By the summer of 1958 the unit had totalled approximately 60,000 hours of operation, averaging 20 hours a day, six days per week. It was shut down for complete annual inspection as part of the plant preventive maintenance program.



Long before the unit was shut down the customer had ordered new main bearings to keep in reserve stock in event of emergency. It was decided to install the new bearings while the compressor was torn down for inspection. When the old bearings were removed they were checked for wear and were found to be within the original one-thousandth-inch tolerance *for new bearings*. This means that there was *no measurable wear*, even after the equivalent of 20 years of "normal" operation!

Of course, these are not ordinary bearings. They are *aluminum full-floating* bearings, one of the extra-value features found only in Ingersoll-Rand compressors. These heavy-duty bearings roll with the punch of each compressor stroke, distributing the load evenly all around the inside and outside of the shell. Their special aluminum alloy has better load-carrying capacity and higher heat conductivity than other bearing materials. And they *never need adjustment*, so the running gear may be kept sealed from dust and dirt.

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For more information, turn to Data Service card, circle No. 114

Computers modestly enter new control era

If restraint is a sign of "coming of age," then computers stepped across a significant threshold last month. For with a minimum of fanfare, two CPI companies revealed they were operating computer controlled process plants: Unlike some of the announcements of a few years ago, which promised all things to all men, the two press releases modestly acknowledged that the computers were controlling a chemical process unit. About the only blatant note was that each claimed to be the first. However, since the announcements themselves were dated on consecutive days, in themselves they tended to negate this one, relatively unimportant, point.

The best thing to be said is that both manufacturers and users are accepting the fact that computers are tools which can help to do a better job. They have limitations—if only economic ones – and potentials which still remain to be discovered.

"Computers can do anything"

In their introductory stages, all sorts of published claims were made for the machines. The "fully-automated, completely integrated, thoroughly simulated, super-feedback, push-button plant" should have been the rule by now if some of these predictions had only been practical. Unfortunately, the over-exuberant claims would not hold water; often because the equipment it was supposed to monitor and control was not properly developed to fit in with the advanced computer. Many a plant control room has seen expensive data logging and computation machines gather dust with the operator preferring his tried and true method over the shiny "monster." While the computers got the headlines, they also were rendered a disservice of sorts by being pushed a bit too far and too fast in some areas.

Lack of available data helped to keep computer users in the dark as to what others were doing. The personal element, which went into much programming, often helped to keep others in the same organization from benefiting from their internal installation. A big corner was turned with the formation of the A.I.Ch.E.'s Machine Computation Committee a little over a year ago. This was set up to exchange information on various programs underway, and each month CEP publishes abstracts of these. Going a step further, the actual programs are gradually being published in manual form so that for a few dollars a company can get a program which cost thousands to prepare.

"Well, maybe not everything"

This is a big stride from the published material of the past, which was a statistical mumbo jumbo beyond the scope of most practicing engineers who had need for the tool but had to find ways to adapt it to the job at hand. In taking a hard look at what the computers could do, the engineers found there were some things they couldn't do—at least not as cheaply as an alternate method. An article in this issue by Dick Hall of DuPont makes this case very well. And in writing he's performing a service to both the manufacturers of the machines as well as the users. For in actuality he's telling the former how best to sell their computer's best points, and the latter how best to evaluate their needs.

The manufacturers have not been completely remiss at all. They have been concerned over information dissemination and have set up users conferences to exchange data on machines of their respective makes. Some have worried over the excessive capabilities of some of their models and have come out with much smaller ones tailored to do relatively simple jobs quickly and economically. One of these was just recently introduced. As witnessed by the recent announcements they are anxious to let the facts supersede "wild blue yonder" prognostications. In short, the computers have come through their shakedown period and now are in much better shape to be used by engineers to do the many jobs which lie ahead.

We'll see more of them put to work than ever before, and we'll see new ones developed to do jobs a bit too far afield at the moment. But be they analog or digital, a combination of both, transistorized, electronic or magnetic, the trend is such that the users and sellers will both be able to approach their jobs more factually and with greater confidence.

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Available in sizes ranging from bench scale laboratory units to commercial 500 GPM units.

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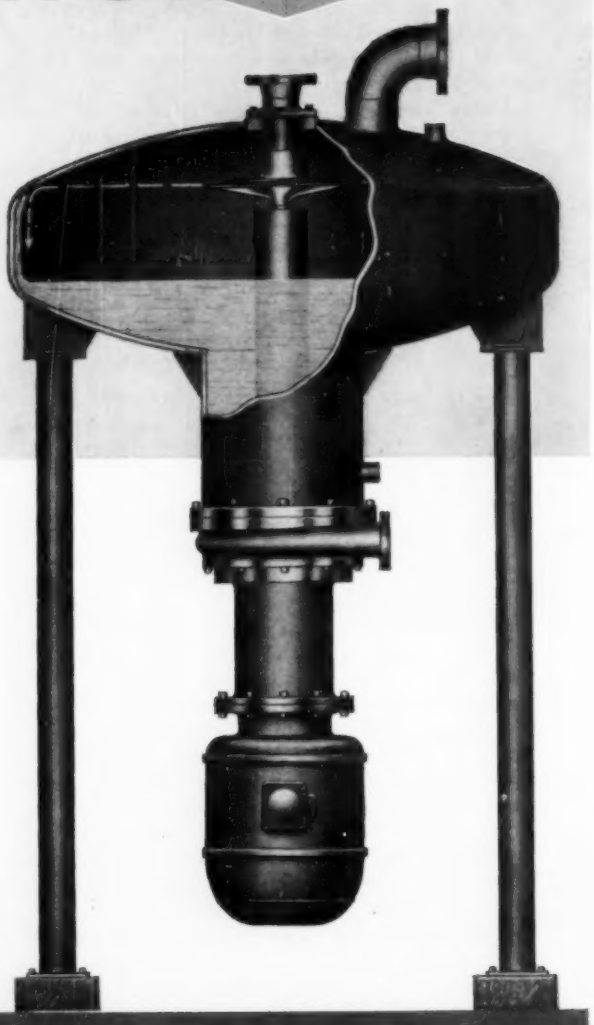

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opinion and comment

Memo to management

In *Harvard Business Review* an article in the January-February, 1960, issue entitled "Thinking Ahead" by Stephen B. Miles, Jr., and Thomas E. Vail views the challenge to industry presented by professional people. In this article, which we recommend to every engineer and to every person who has anything to do with managing or utilizing engineers, the authors make such statements as, "The time has come for businessmen to face up to the crucial question of how best to 'manage' professional employees . . . decision and policy making are becoming more and more dependent on technical and specialized knowledge . . . . Often these are the men [the professionals] who must make the business decisions and must form the basic policy for a company . . . . The essence of decision making in the role of the manager is tending to split off from his supervisory function."

We applaud the research done for this article, for it points up many editorials we have written along the same lines—about the importance of chemical engineers in the chemical process industries and the need to recognize their achievements. The executive or administrator of a business enterprise makes decisions to spend money, but it is the engineer who actually spends it. The engineer decides how the money is to be used and selects the processes and equipment for whatever enterprise the executives have approved; indeed this very approval often rests on the facts that have been developed by the engineering staff.

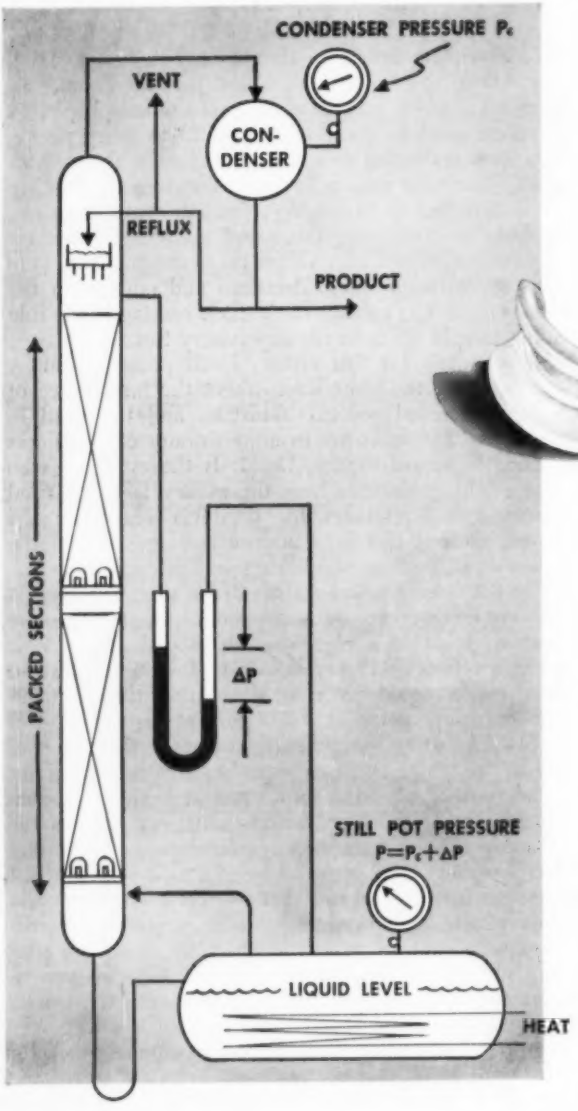
To the managers of business enterprises—in the sense of the generalist in management, not the engineering manager—we should like to say some other things. The chief engineer of a company whose plans for a new project give the company a return of 18 percent on its investment instead of 16 percent deserves as much consideration as, if not more than, a financial vice-president who borrows money at 4.076 percent instead of 4.75 percent. We also humbly suggest to the generalist manager that the specialist executives, such as the plant manager who has the respect of his workers so that there are no wildcat strikes in a plant and whose production and efficiency records are of the best, deserve as many pats on the back and stuffing of the pay envelope and bonus arrangements at the end of the year as does the personnel manager who negotiates a new contract with the union. May we go further and say that the plant engineer who makes corrosion studies which keep production units operating months longer than normally, or who controls quality in his plant in such a way that he is able to buy cheaper chemicals and thereby increase profits, deserves as much recognition as the district salesman who sells the results of the engineer's production ingenuity.

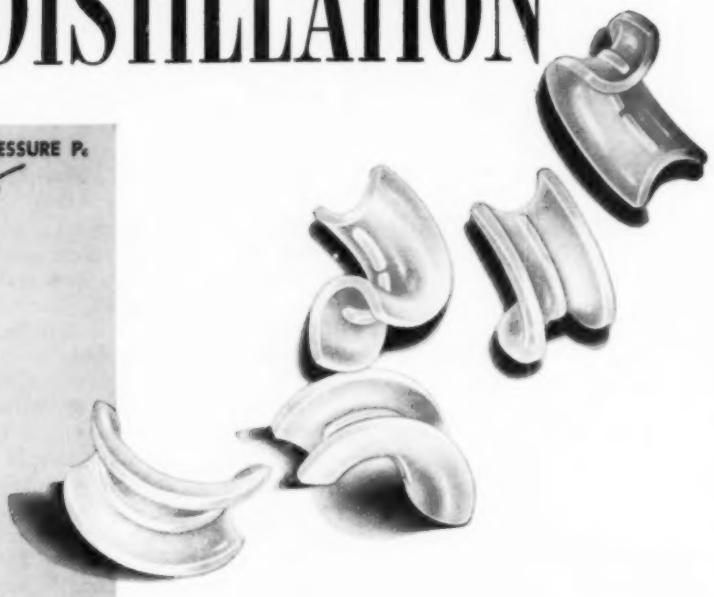
Most engineers, as we have said many times in these columns, work for other engineers, and it seems to us that the engineers who are in the top echelon should at the meeting of the board of directors talk a little more and brag a little more about the vital part that engineers play in the success and health of their particular enterprise. Unless this is done, and done intelligently, and unless engineers are rewarded with the same satisfactions that keep a generalist management going, there will rapidly come about what the *Harvard Business Review* authors noted as a trend that caused them to write the article in the first place: "In recent years more and more groups of scientists are 'walking out' on management to form their own companies. Here they feel that they can control new projects from conception through design and development to production and test . . . . They are . . . reluctant to entrust their brain children . . . to managers . . . ."

F.J.V.A.

How to Lower Pot Temperatures in

VACUUM DISTILLATION





One of the important aims in vacuum distillation is to maintain as low an operating temperature as possible. High temperatures are injurious to many organic materials. Particularly, in batch operations, where virtually all the heat must be supplied to the liquid in the pot, losses due to pyrolysis can be substantial.

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Chemical growth potentials climbing in Central U.S.A.

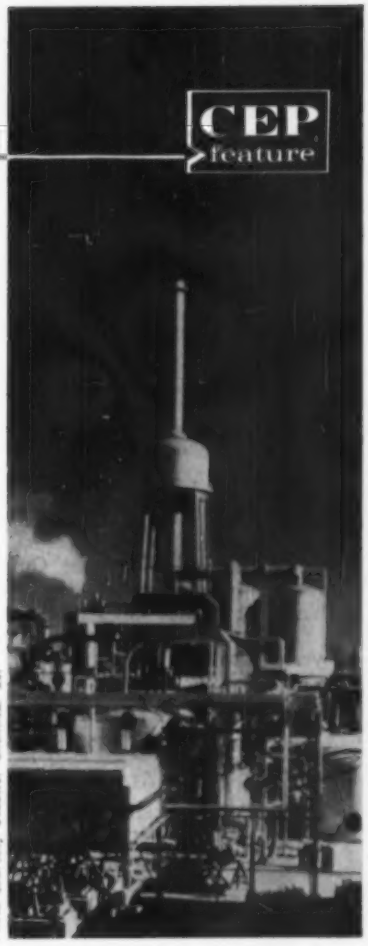


Photo courtesy Stauffer Chemical Co.

FUTURE NATIONAL GROWTH, plus exploitation of its natural resources and its geographical location, combine to forecast unprecedented development of the area of the Central United States. And with its general development must come its chemical growth.

Sulfuric acid, nitrogen, chlor-alkali and petrochemicals are basic to the future of the chemical industry as a whole, and, naturally, to its growth in this region. A quick look at these four aspects of the industry in the area leads to a consistent overall conclusion: the outlook is bright.

Sulfuric Acid . . . .

J. H. ZWEMER and C. M. DEAN

Daily production capacity expected to increase to 25,000 tons by 1975. That's up from current 15,000-ton regional capacity.

SULFURIC ACID, the "work horse" of industry, is the largest tonnage product of chemical industry. Its production in 1957 was roughly eight times that of aluminum, seven times that of copper and a third more than that of lime. It is not a detectable part of a supersonic jet plane, a rocket to explore space, a miracle drug or an electronic computer, but without it these and most of our daily needs could not exist. Even with so fundamental a position in the chemical industry, sulfuric acid is affected by many factors that must be considered in forecasting its future: Available raw materials, price trends and availability of the product itself when and where needed.

The raw material situation is complex because of the great number of source materials available. The more important are:

(1) Frasch-process and recovered elemental sulfur, as well as crude elemental sulfur ores.

(2) Metal sulfides, such as pyrite, pyrrhotite, zinc and copper sulfides.

(3) Hydrogen sulfide from oil refineries and "sour" natural gas.

(4) Sludge and spent acids from refineries and organic processes.

More and more sulfuric acid is being recovered from by-products for two very good reasons: (1) to prevent air

and stream pollution, and (2) to realize values heretofore uneconomical to recover. For example, a refinery can manufacture sulfuric acid from burning waste H_2S or sludge acid.

In 1955, with a total U. S. population of 175 million people, six million long tons of sulfur were consumed. By 1965, with an estimated population in the U. S. of 195-200 million, sulfur consumption should approach eight million long tons. If it continues to follow the Paley Commission prediction, it will reach approximately 10 million long tons in 1975, twice as much as in 1950.

All indications are that ample supplies of sulfur will be available to meet the predicted consumption over the next few years at a normal growth rate. Considering the midwestern area specifically, raw material for sulfuric acid manufacture will continue to come predominantly from the Gulf Coast area in the form of Frasch-process sulfur. There are indications that more and more sulfur will be recovered from natural gas as the petroleum industry continues to probe for more oil.

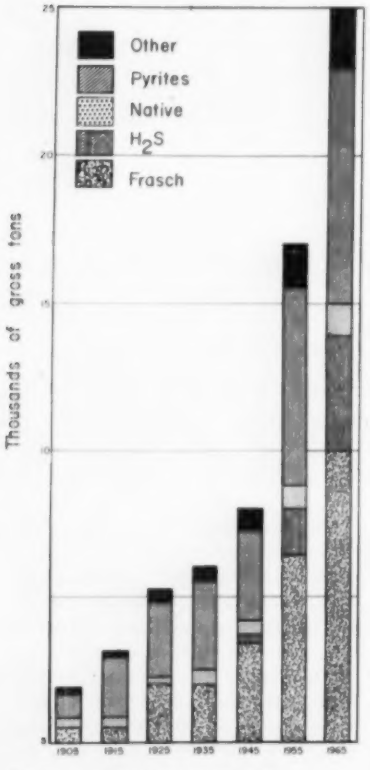


Figure 1. World sulfur supply.

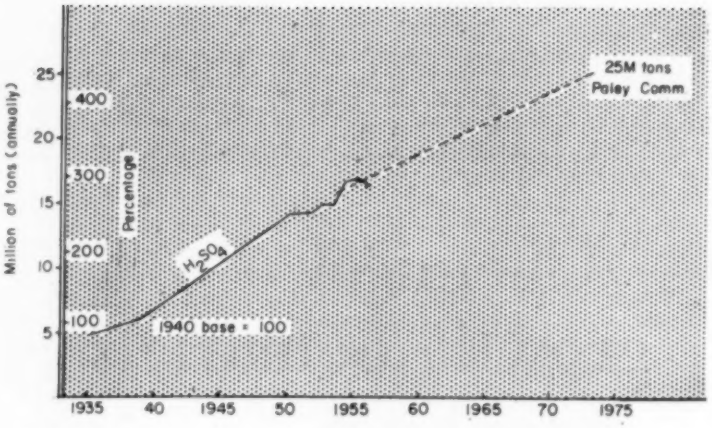


Figure 2. Annual sulfuric acid production.

With the exception of the rayon industry, end uses have had very good growth patterns. However, this is not the whole story needed for determining a future trend. Changes in individual industries may or may not include the use of sulfuric acid. For example, fertilizer makers used 40% of all sulfuric acid produced in 1940, but only 35% in 1955. This is due to increasing consumption by other industries and "leveling off" of demand by the fertilizer industry.

While the use of sulfuric acid in the fertilizer industry was "leveling off," chemical use jumped from 13% in 1940 to 21% in 1955. The chemical industry will continue to depend upon this cheap acid in its growth. The petroleum industry has been a steadily growing outlet for sulfuric acid and promises a solid future. Should the future swing toward nuclear fuels, sulfuric acid already has a foothold in this industry for the processing of uranium ores. The steel industry production swings with the national economy and uses sulfuric acid in proportion to steel production. There appears to be no good substitute for sulfuric acid as a pickling agent so that continued use can be expected.

Use of sulfuric acid in the future will also depend upon price. In the past twenty years the price has ranged between $17 and $23 per ton on a national average basis. This is a small increase compared to the increase for other products that go to make up our cost of living. We doubt that a similar increase in the price of sulfuric acid over the next 10-20-year period would affect its widespread use.

The Paley Commission report concluded that the nation would require 25 million tons of sulfuric acid by 1975. This appears to be a conservative figure in that 16 million tons were produced in 1957.

The 25 million ton production of sulfuric acid by about 1975 is 155% of the production for the year 1957, while the Federal Reserve Board figure for all industrial production is 150% of that for 1957. The Federal Reserve Board chemical production for about 1975 is 185% of that for 1957. From these comparisons, it is seen that the sulfuric acid production forecast by the Paley Commission is illuminating but low.

Since the Paley Commission Report was based on the 1950 figures for production, it is interesting to note how total production has correlated with the forecast, even though some of the forecasts for individual uses were

Zwemer

Dean

J. H. Zwemer joined Monsanto in 1936 after obtaining his MS from the U. of Michigan. After early work on organic chemicals, he became plant manager of Monsanto's Norfolk operation. A five year stint as general manager, production and research, for Smith-Douglass Co. preceded his return, in 1958, to Monsanto as asst. director of engineering sales. C. M. Dean, who wrote the latest revision of the sulfuric acid section of the Encyclopedia Britannica, has been with Monsanto since 1930 when he was superintendent of the Acid Division. He became director of engineering sales in 1952.

in error. For example: Ammonium sulfate production was to increase 200% but actually there was no increase from 1950 to 1957 and it is generally predicted by fertilizer authorities now that perhaps its use will decline as a fertilizer. At the same time a considerably greater upsurge than predicted in the use of sulfuric acid for wet phosphoric acid production more than offset the ammonium sulfate loss. This illustrates that while the individual product forecast may be in error, the final composite of all individual uses may be essentially correct. This is further evidence that estimates of future production of products that are used widely throughout all industry, such as sulfuric acid, can be made with a fair amount of accuracy, barring unforeseen national emergencies or catastrophes.

End uses of sulfuric acid include:

Fertilizer	35%
Other chemicals	25%
Petroleum industry	11%
Pigments	9%
Steel industry	6%
Rayon industry	5%
Other uses	9%

The present daily capacity of production of sulfuric acid in Central United States (excluding Texas) is 15,000 tons, less than one third of the national capacity of 52,000 tons. The upsurge in sulfuric requirements for fertilizers is expected to begin in the middle 1960's when the increased population in the country will have reduced the large surplus of farm products. On this basis, in the year 1975, the daily capacity of sulfuric acid in the Midwest may be 25,000 tons, an increase of two thirds over the present capacity. #

The Nitrogen Industry . . . .

FRANK O. AGEL

Nitrogen demand of 3,000,000 tons in 1975 will be half total U. S. demand at that time. Modest capacity increase looked for with annual capacity of 2,600,000 already installed in area.

NATIONWIDE CONSUMPTION of fixed nitrogen almost trebled from 1,100,000 tons in 1947 to 3,100,000 tons in 1958. During the same period, consumption in the Central States nearly quadrupled from 400,000 tons to 1,550,000. The growth rate for the nitrogen industry during this period was among the highest in the chemical industry and that as a whole grew at three times the average rate for all industry.

The Central States consumption pattern has been similar to the national pattern. The Central States have taken a gradually increasing share of the nitrogen consumed until today the area uses about 50% of the total and of the agricultural nitrogen consumed in the country. Nitrogen to agriculture throughout the postwar period has been substantially constant at 75% of the total nitrogen consumed in the country and in the Central States. Agriculture has thus been dominant in the industry's growth.

Production in the nitrogen industry leads one inevitably to ammonia although the market for ammonia alone is somewhat limited; most synthetic nitrogen is consumed in nitrate or other combined forms. The nitrates are made by catalytic oxidation of ammonia which process results in a significant loss of nitrogen from conversion inefficiency. Processes to fix nitrogen directly with oxygen, most recently the Wisconsin Process, have not proved competitive with the ammonia route.

Of the ten ammonia plants in the U. S. in 1932, only one small plant, accounting for 3% of the total productive capacity, was using natural gas as the source of its hydrogen: the bulk of the hydrogen then used in the industry was derived from coke. By 1959, economic considerations dictated an almost complete conversion to natural gas or by-product refinery gas, with about 87% of capacity now based on these sources. Two recently installed ammonia plants are operating on coke-oven gas and one projected for North Dakota considered lignite. If the prices of natural gas and petroleum increase, future economics may again favor solid fuels, such as coal or lignite, as hydrogen sources. Of 59 ammonia plants in the United States,

continued

Frank O. Agel joined the Solvay Process Div. of Allied in 1927 after receiving his BS from Cornell. He worked on the original design and operation of the Hopewell Ammonia plant. Serving as principal chemical engineer in the development dept. of the Nitrogen Section from 1939 to 1951, Agel played an important role in the expansion of the nation's ammonia capacity. In 1952 Agel became director of development, and in 1958 was appointed vice president of the Nitrogen Div. in charge of R&D.

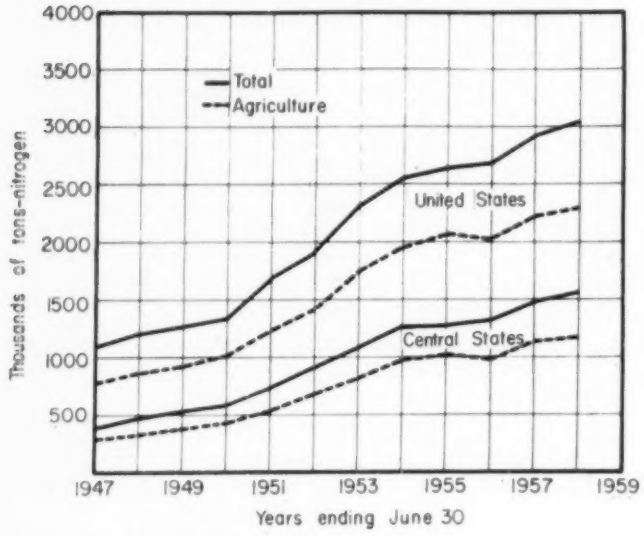


Figure 1. U. S. and Central States nitrogen consumption.

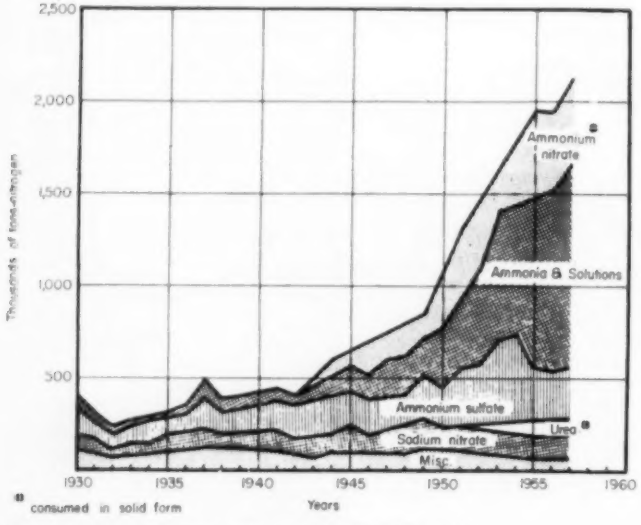


Figure 2. How nitrogen gets to agriculture in U. S.

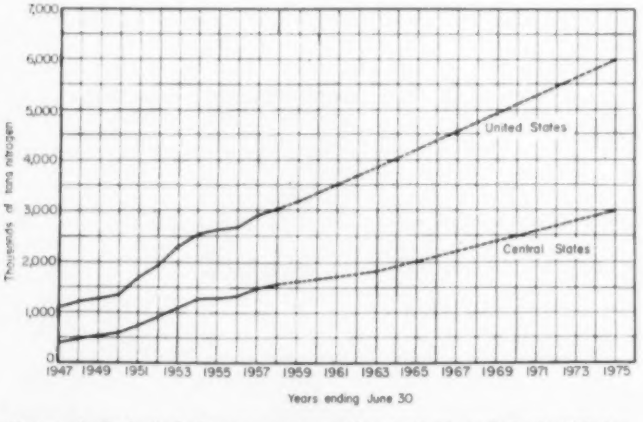


Figure 3. Projected nitrogen consumption in U. S. and Central States.

32 having a combined annual capacity of 2.6 million tons of nitrogen are located in the Central States area. All but six of these plants utilize natural gas or petroleum as the source of their hydrogen. The plants in the Central States area constitute 54% of the plants and 62% of the total capacity of the United States, a remarkable growth from only two plants in 1940 with a total annual capacity of only 8000 tons of nitrogen.

Following rapid growth in both productive capacity and consumption from 1947 to 1954, an imbalance developed in the industry that today gives a surplus of capacity over consumption of about 1 million tons of nitrogen per year. Industry-wide, this means that 25% of installed capacity is not now being used, a figure estimated to be as high as 40% idle capacity in the Central States where growth of productive capacity has been greatest in recent years.

In the five-year period, 1958-1963, population and market requirements for farm products are expected to rise about 7-8%. But the annual flow of products from farms in the last few years has exceeded market requirements by as much as 4% annually according to Department of Agriculture figures. This may be expected to continue under government control, and agricultural production rates and fertilizer demand are unlikely to increase very rapidly.

To offset this, a number of new outlets for nitrogen may open appreciable new markets:

Agriculture

1. The economics and techniques of forest fertilization continue to receive intensive study.
2. Combinations of urea and formaldehyde look promising for providing nitrogen in slowly available form.

Industry and defense—raw materials

1. As the defense program develops, new ways may be perfected to utilize more effectively the older nitrogen-containing materials, such as ammonium nitrate, nitroglycerin, and TNT.
2. Nitrogen-containing synthetic fibers such as nylon, Orlon, Acrilan and Dynel have been on the market for some years, and others are in various stages of development.
3. Nitrogen compounds are becoming increasingly important in the rocket program as oxidizers and fuels.
4. Ammonium nitrate in quarrying and strip mining has continued to

increase rapidly in competition with other explosives.

Industry—processing chemicals

1. Ammonia in wood pulping is gaining acceptance in the paper industry.
2. Plastics and Textile finishes based on nitrogen materials, such as urea and melamine, show good growth potential.

For short range, the assumption that the 1950-1954 rate of growth will be resumed appears unwarranted. It is suggested this rapid increase in consumption may have been deferred demand, and decrease in average annual growth rate since domestic capacity exceeded consumption in 1954 appears to support this view. We believe that an average annual increase in consumption of 100,000-150,000 tons of N from 1958 to 1963 is likely. This means excess capacity will still exist in the U. S. in 1963 and more so in the Central States.

One of the more predictable factors in the long range growth of the nitrogen industry is demand resulting from population increase. Dr. Rex F. Daly of the USDA has summarized 1975 requirements over 1956 as follows: (1) an increase in crop production of one third and (2) an increase of at least 40% in need for livestock and livestock products.

Production of food needs for 1975 will have to be obtained from substantially the same farm acreage available at present. Thus, the productivity of those acres now under cultivation will have to be increased. Higher yields per acre are being routinely obtained by agricultural experiment stations and progressive farmers through use of fertilizer at higher application rates. Based on current European practices, the potentialities of this approach have only begun to be realized in the U. S. For example, compare annual average U. S. consumption of 10 lb. N per arable acre with 31 in the United Kingdom, 46 in West Germany, and 156 in the Netherlands.

Thus, the long range prospects are an increasing market for present and many potential new uses, some of which will surely materialize. Total nitrogen demand of about 6,000,000 tons N will probably be attained in the United States by 1975 with about 3,000,000 tons of this demand required to fill the needs of the Central States. Obviously, with 2,600,000 tons of annual nitrogen capacity already installed in the area, only a very modest increase in capacity will be required to meet projected 1975 requirements. #

The Chlor-Alkali Industry

WILLIAM H. MCCONNELL and KEMBLE S. LEWIS

All factors, including a slower growth rate in the past, point to accelerated growth in the future for whole country and will affect the chlor-alkali industry.

NATIONAL FUTURE GROWTH and exploitation of resources combine with central geographic location to give unprecedented acceleration to the development of the Central United States—and the chlor-alkali industry will automatically participate in this growth. Chlorine, caustic soda and ash are the three largest tonnage products of this industry. Numerous other related products are also made. Chlorinated solvents, organic intermediates, and agricultural chemicals are examples of chlorine-requiring products manufactured captively by chlorine producers. Similarly, numerous gradations of alkalies other than caustic soda and soda ash are marketed by the alkali industry. Bicarbonates, sesquicarbonates, potassium-based alkalies, silicated alkalies and special blends for various cleaning applications are familiar.

Of the industry's three principal products, chlorine has enjoyed the most rapid rate of recent growth. Nationally, production of chlorine has grown at about a 10% average annual rate during the period 1948-1957. It reached 3,947,000 tons in 1957. By far the biggest "appetite" for chlorine, country-wide, is in the manufacture of chemicals: an estimated 82% of the total output goes for this purpose. Pulp and paper, the next largest consumer, requires 14% of the total. Lesser quantities for sanitation, textiles, and export make up the balance.

McConnell

Lewis

W. H. McConnell joined Diamond Alkali in 1928. A Business Administration grad from Penn State, he became asst. director of sales for Diamond in 1945, director of sales in 1946. In 1953 he was made vice president for sales, and named to his present position of vice president for marketing in 1958. K. S. Lewis, market analyst in the General Sales Dept. has been with Diamond since 1947. From 1948 to 1954 he was with the Chicago Branch sales office, becoming product sales manager, Plastics Div., in 1954. Lewis is an MS graduate from U. of Michigan.

The consumption pattern in the Central United States is similar. Chlorine producing facilities in Wichita, St. Louis and Calvert City consume substantial portions of their output in captive operations making chemicals. These three captive operations are estimated to require about 125,000 tons of chlorine per year (roughly 45% of the chlorine producing capacity in the area) for chlorinated solvents, agricultural chemicals, other chlorinated organic products and hydrogen chloride.

Beyond these three major concentrations, use of chlorine in this area for chemical manufacture is rather widely dispersed, product-wise and geographically. Chlorine is used to produce sodium hypochlorite bleach in large plants in St. Louis and Kansas City and in smaller plants throughout the area. Chlorinated cornstarch in Iowa, metallurgical requirements in Arkansas, and muriatic acid for acidizing oil wells represent a few examples of other chemical requirements.

In the pulp and paper industry, chlorine has been supplanted or supplemented to a limited extent by chlorine dioxide; however, it is still used in sizeable quantities by the concentration of mills in Arkansas and by mills elsewhere in the area.

Sanitation—the treatment of water and waste by municipalities and industry—requires increasing quantities of chlorine. More stringent stream pol-

continued

lution laws, coupled with greater utilization of available water sources, have meant more use of chlorine for sanitation.

United States' caustic soda production in 1957 reached 4,348,000 tons. On a national basis, chemicals consumed the greatest tonnage. Rayon-film, pulp and paper, soap and cleaners, and petroleum refining are other chief consumers.

In Central United States, caustic soda is also used in making a wide range of chemicals. While there are no rayon plants in this area, three cellophane plants located in Kansas, Iowa, and western Indiana are capable of consuming in excess of 70,000 tons per year. Petroleum refining operations in the area require an estimated 33,000 tons per year. Pulp and paper plants and soap and detergent operations, large and small, throughout the area add to caustic consumption.

Nationally, soda ash production in 1957 totaled 4,995,000 tons, which is greater than the tonnage of either of the other two products. The largest consuming industry is glass manufacturing with heavy concentrations of glass plants in Illinois and Oklahoma. Chemical manufacturing runs a close second. Soaps and cleaners, metals processing, pulp and paper and

Chlorine-caustic soda and Soda ash plants

Petrochemical Industry

THOMAS L. CUBBAGE

Future growth in central states not tied to past performances; specific segments of the industry must be considered, and new growth factors may have important impact.

IT IS EASY TO ENTHUSE about the future of the petrochemical industry. But few people have the insight and imagination to do justice to the actual growth we fully expect in the next decade. The industry is continuing to ramify and is growing in new directions all the time. Perhaps our best course is to trace out some of the present leads the industry is following, always realizing that mere projection of the past is unlikely to fit the future.

1. Ammonia plants scattered over the area of the Central United States have been largely built in the past ten years. An ample supply of ammonia and stiff competition in the fertilizer market effectively prevents expansion at these plants much beyond the requirements of the surrounding marketing area. Future growth can be gauged by the demands of the local markets for fertilizer nitrogen.

2. The automobile tire industry, largely located in the eastern states, with a heavy concentration around Akron, Ohio, once drew its requirements of carbon black almost entirely from the Texas Panhandle and western Kansas. The long freight haul for this important rubber chemical could not be avoided because this was the only location where adequate gas was available. Also, the production of channel black is an inherently smoky, air-polluting process best accomplished at a distance from any urban development and so well suited to this western location.

A few channel black plants still operate in West Texas but no new capacity is being built. Instead, new plants make only the oil furnace blacks; these give superior performance when compounded with synthetic rubber. Stack gas from the oil-furnace black plants can be made quite clean by use of bag filters, and carbon black production is no longer oriented to cheap gas supply and an isolated production area. New plants are springing up in the Gulf Coast area alongside refineries that can furnish the special oil feedstocks. That area also provides cheaper transportation to both U. S. and foreign rubber compounding centers.

3. At several locations in the area only petrochemical raw material is produced—a stream of pure aromatic, olefin or paraffin, a polymer stream such as diisobutylene or propylene tetramer, or an oil stream suitable for carbon black feedstock or for rubber compounding. An operation to use these intermediates may not be justifiable at the location.

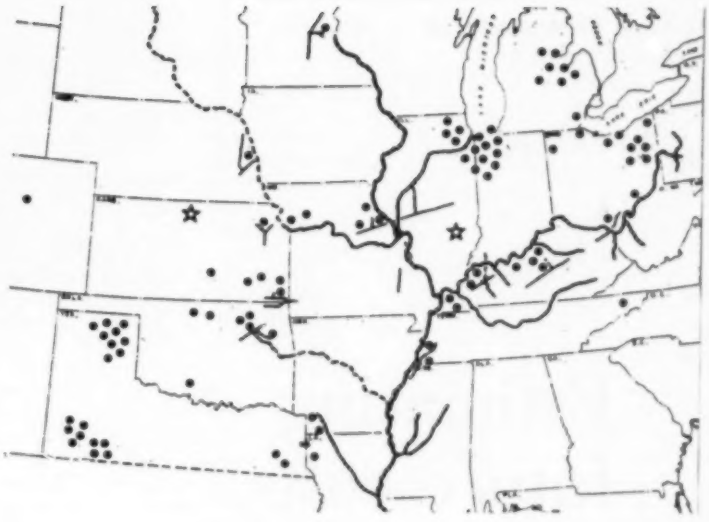
4. The Mississippi waterways system, including proposed extensions to the navigable system on the Missouri and Arkansas Rivers, has attracted operations to utilize this important water transportation.

5. Petrochemical operations have also located with respect to large refinery operations, as at Chicago and St. Louis, and with respect to natural

water treatment are other major markets.

Producing facilities for soda ash are located around the periphery of our central area. The more concentrated areas of consumption in Illinois, Oklahoma and Arkansas are adequately served by plants in Michigan, Ohio, Louisiana and Texas. The Wyoming plant, producing soda ash from trona, can serve most Central U. S. locations.

In looking toward the future of caustic soda and soda ash, we must look first at the future of the country as a whole. All indications are that the 60's will be booming times for business. The future will hold more than a mere projection of the current trends. Technological developments will bring forth new products and create new industries that cannot be envisioned today. New plants will be required everywhere to satisfy the enlarged national appetites. Within the area of the Central United States, all factors, including a slower rate of growth in the past, point to accelerated growth in the future. This will also affect the chlor-alkali industry.



Central U. S. A. refineries

gas pipelines. Ammonia synthesis based on by product hydrogen, pure hydrocarbons, detergent intermediates and various higher boiling oxygenated hydrocarbons comprise the main refinery petrochemicals in the area. Ethylene derivatives and lower molecular weight alcohols, aldehydes, etc., are all based on light hydrocarbons from natural gas. The outstanding light-hydrocarbon petrochemical operations in the area include Dow Chemical Company at Midland, Michigan; National Petrochemicals Company at Tuscola, Illinois; Olin Mathieson Chemical Corporation at Brandenburg, Kentucky; and Texas Eastman Company at Longview, Texas.

The future growth of the petrochemical industry in the central states is not going to be simply an extrapolation of past performance, either as to rate or pattern. Specific segments of the industry must be considered in predicting future growth and new growth factors may have an important impact:

(a) With its ability to produce over 4,500,000 tons annually compared with demands from agriculture and industry totalling only 2,700,000 tons, the ammonia industry is currently suffering from acute overcapacity. No expansion is foreseen until available capacity is more fully loaded. Increased food demands of our swelling population must ultimately boost nitrogen fertilizer production above present levels.

(b) Aromatics will become more generally available at refineries and a more extensive chemical program based on aromatics may develop. Benzene, toluene and the xylenes are starting materials for many relatively high priced intermediates for the rubber and plastics industries.

(c) Although producers of large volume, low-priced petrochemicals are obliged to locate close to markets or near cheap transportation of their products, this is less important to the producer of higher priced specialty chemicals. Availability of research facilities and trained technicians may be the key to a best location for specialties manufacture. Many locations in the Central States have much to offer in this regard.

(d) Acetylene production in the Central United States area is almost entirely obtained from calcium carbide. So far, the production of petrochemical acetylene, using natural gas or light hydrocarbon as feedstock, is confined to the Gulf Coast. Cheaper raw material is probably the major reason for this. Improved processes now available for the production of petrochemical acetylene need careful study. Acetylene-derived petrochemicals could get a big boost in this area, if acetylene made from natural gas becomes competitive with carbide acetylene.

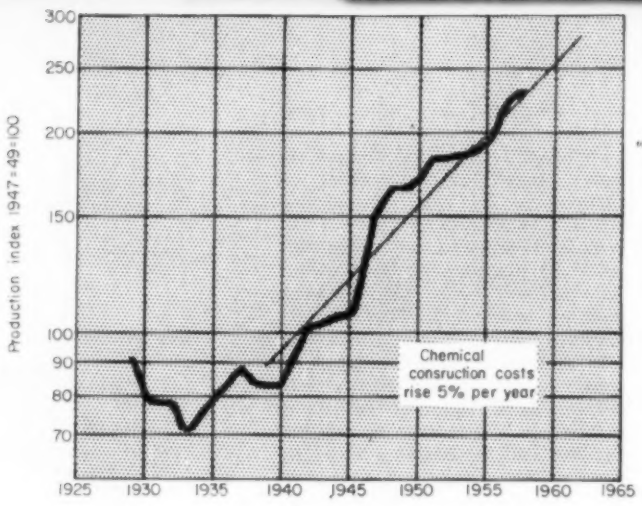
(e) Most ethylene production now comes from cracking ethane, propane, or butane and the Gulf Coast region attains special importance in the ethylene picture largely because of availability of these feedstocks. In spite of the many gas pipelines crossing the Central States area new ethylene operations such as those at Tuscola, Illinois or Brandenburg, Kentucky, are unlikely.

This area is at a disadvantage in the production of ethylene chemicals as long as processes requiring light hydrocarbon feed stocks are used. Economical production of ethylene from heavier oil fractions would be an auspicious development for this area.

Future growth thus depends on many factors; only constant study and an intelligent insight into the significance of developments can pinpoint the important situations. Important growth may be the result of favorable factors plus your bright ideas on how to make them work.

T. L. Cubbage is vice president and general manager of Phillips Chemical Co. (Phillips Petroleum). Joining the company in 1926, Cubbage was made asst. superintendent of the Plains butadiene plant in 1943, superintendent in 1944. He moved to Bartlesville general headquarters, and his present position, in 1951.

WILLIAM COPULSKY and
RUDOLF CZINER



Estimating future costs

Some tips on how to anticipate the costs of developing and operating chemical process plants.

ESTIMATING PRODUCTION COST, plant investments, and profits has become a highly developed art among chemical engineers. Such activities are accepted as an integral part of nearly every stage of development and research, planning, and most other phases of running a chemical company. It is surprising, therefore, to find that most companies are satisfied with estimates reflecting only current conditions—today's prices.

This seems unreasonable. Chemical technology is becoming more complex every day. It now takes an average of two years to build and run a new plant efficiently, even where the plant is practically a duplication of an existing unit within the company. Five- to ten-year payouts are common. Proper planning demands that costs and profits be evaluated on a dynamic basis.

Where such needs are recognized, cost estimates are sometimes prepared for one or two years ahead, usually by applying some over-all escalation factor to the total costs, without any attempt to examine individual cost components. Yet, a more detailed examination of individual costs may prove quite valuable.

The forecasting of costs and profits should provide management with a tool that is valuable in many ways. It will show the trends in the costs and profits of a product or series of products. A detailed study will also highlight the relative importance of individual costs in the future profitability of the products, and may point to production factors which must be watched carefully and modified, if possible.

Actually, all that is proposed here is that two arts of chemical management be combined to yield a dynamic management tool. It makes use of the talents of the chemical engineer for calculating cost estimates, and of the economist and market evaluator for predicting future costs and prices. Both arts require talent, knowledge, and experience, especially the last item.

Nothing need be detailed here on cost estimating. This discussion will deal mainly with forecasting such costs and showing some results. Forecasting can take many forms. **Historical trend analysis** is an important method. In this, past data are studied to determine their trends, and such growing and declining trends are extrapolated for a short period into the future.

A refinement of trend analysis is cycle analysis, where the effects of business or social cycles on an individual commodity or service can be examined and forecast. The insect infestation cycle in the U. S., for example, has an important bearing on the demand of pesticides.

Another important forecasting technique is **correlation analysis,** where an economic factor under consideration is related to some independent, predictable economic or social phenomenon. A good example of this kind is the correlation of U. S. chemical production to the Gross National Product of the country.

The **survey of executive and business opinions** is probably the easiest method available, but often is also the most misleading. This procedure is simply a compilation and evaluation of predictions and opinions by various experts. As such, it usually reflects the current vogue or mood of the industry and business community, and does not demand too much independent thought from the forecaster.

Usually, two or more methods will be used for reliable forecasting, depending upon the degree of accuracy required and the data available. This presentation combines mostly trend-analysis and the survey-of-executive-opinions methods.

Typical components of a cost estimate are shown in Table 1. For the

purpose of this discussion, only an over-all plant investment figure is used. Production costs are broken down in detail (too many for most forecasting purposes). Sales expenses are added to this list. All these individual components, however, will be discussed later when a sample cost estimate will be presented.

Economic conditions

For the next five years, the U. S. economy is expected to experience a growth trend fairly similar to the 1955-1958 period. By 1964, neither a major military conflict is expected to develop, nor any substantial reduction in the expenditures for military and defense purposes. Such budget items should be maintained somewhere along current levels.

For the past five decades, the purchasing power of the dollar has been decreasing at an average of 2.5%/yr. In other words, prices have been increasing at this rate. Figure 1 shows these trends in the prices of consumer products. Actually, since the depth of the depression, the consumer price level has increased at a sharper rate; but since 1947, the price rise has returned to the 2.5% annual trend. In recent years, inflation has been kept even further in check. During 1959, it will probably be only about 1.5%.

This illustrates an important fact. The trend lines (or annual rates of increase) may vary widely with the period of years considered (or the base year used). In effect, it is important to recognize the changes in these trend lines or rates of change.

In examining the trend in inflation, it becomes obvious that the consumer price index has been increasing at a decreasing rate. In consequence, a curb on the use of the consumer price index is indicated. This should be due to such factors as active government intervention in the economy, more careful government budgeting, a new balance in the bond and equity markets, a less favorable balance of trade, etc. Most important, the public has become very conscious of inflation. Despite all types of pressures, the government should reflect this public sentiment, no matter who wins in 1960.

The net result should be a further modification in inflation, with the average annual increase to 1964 expected only at 1%/yr. It is interesting to note that chemical prices since 1947-1948 have increased at a slower rate than consumer products, averaging only about 1%/yr.

The Gross National Product (GNP) is an excellent measure of the state of the economy. It reflects the sum total of the value of all goods and services produced by the country. Since 1929, the GNP has had a very rapid growth rate, averaging about 5.5%/yr., Figure 2. On a deflated basis, in 1957 dollars, the average growth has been only 3.0% annually. This 2.5% difference is the inflation factor previously mentioned.

The 3% growth rate for the real GNP is expected to continue under the assumptions made above. Since inflation is expected to continue at only 1%/yr., the GNP in current dollars is predicted to rise a total of 4%/yr., on the average, during the next five years. This puts the 1964 GNP at $570-580 billion (in current dollars).

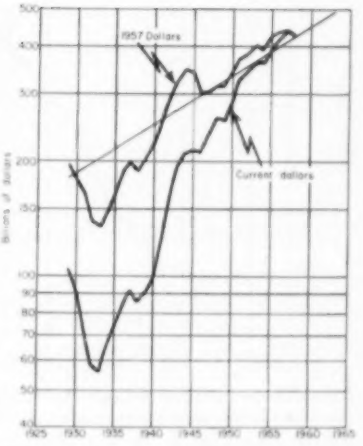


Figure 2. The Gross National Product has risen about 5.5%/yr. since 1929.

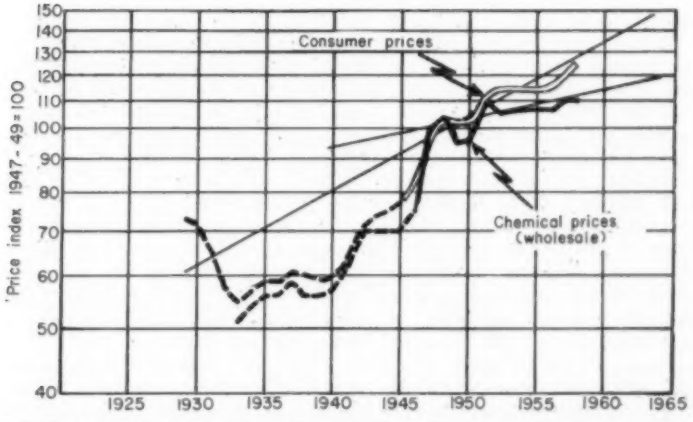


Figure 1. Decreasing purchasing power of the dollar, or; the trend of increasing prices.

Costs

Plant investment, including both actual construction costs and the various auxiliary costs associated with a new plant, are expected to increase at an average rate of 5%/yr. This is consistent with the past record of chemical construction costs, as indicated by the Marshall & Stevens Index in the graph on page 46. This means a 28% rise in construction costs by 1964.

The working capital depends mainly on the costs of inventories and other short-term cash requirements. For simplicity, such working capital can be raised by the relative change in both production and sales costs.

Raw materials must be evaluated on an individual basis. Each major component of material input should be examined historically, and its future supply and demand weighed, to estimate future costs. For the hypothetical example presented later, a 3%/yr. price increase will be used.

The hourly wages of chemical production workers can be used as a

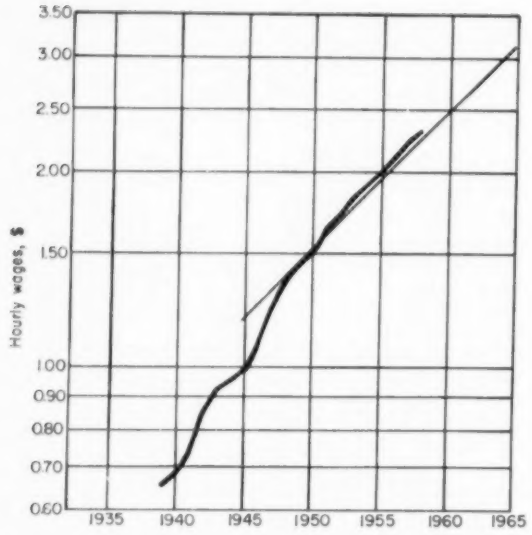


Figure 3. In the past decade, the hourly wages of chemical production workers has risen at slightly higher than 5%/yr.

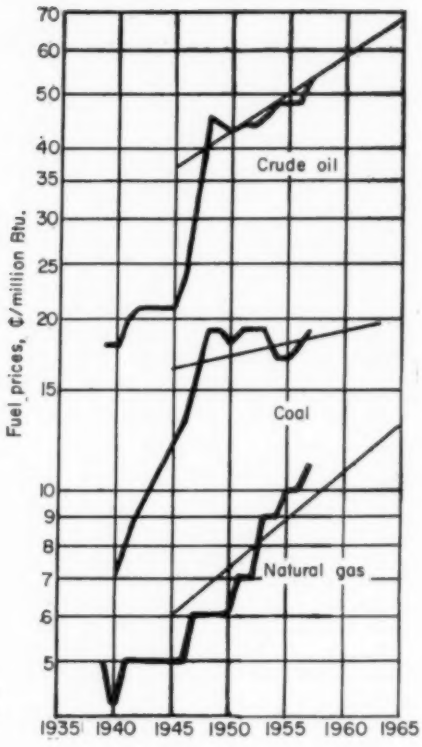


Figure 4. Fuel prices are governed by many factors.

measure of labor costs; both wages and labor overhead. Figure 3 shows these data since 1939, as compiled by the Bureau of Labor Statistics. In the past decade, such wages have risen at a rate slightly in excess of 5%/yr. There is little to indicate any reduction in this inflationary move. A 5%/yr. wage increase can be considered reasonable. This 5%/yr. increase should consist of about a 3.5% rise in real, deflated wages, a 0.5% decrease in working hours, and the 1.0% inflation factor.

Fuel prices are governed usually by long-term contracts, geographic location, and local conditions. The price history of crude oil, coal, and natural gas at the well or mine are shown in Figure 4. Crude oil can be expected to rise 3%; natural gas, 4%/yr. The expected 4% increase in gas costs represents field-related cost, about ¾ of the total costs. The other ¼ of such costs should follow the 1% inflation increase, resulting in a combined increase for gas of 3.25%/yr.

Table 1. Components of typical cost estimates.

Capital Investments	
Plant investment	Working capital
Production Costs	
Raw Materials	Supplies
Labor	Packaging
Utilities	Laboratory
Gas	Plant Overhead
Steam	Taxes and Insurance
Water	Administration
Electricity	Depreciation
Maintenance	Freight Allowance
Sales Expenses	

Coal prices have fluctuated in recent years, with no discernible trend. Prices have been stable due to the benefits of mechanization. Productivity in mines has shown a fairly spectacular improvement during the past decade. Productivity is not expected to continue to increase in the future. The inflationary trend should start to take effect in the future at about 1%/yr.

Of the various utilities, steam costs depend on the source of energy. In the example cited later, gas-derived steam is used, increasing 3.25%/yr. Both water and electricity costs are assumed to have cost trends in line with inflation, 1%/yr.

An index of plant maintenance costs was published until recently. Such data from 1947 through 1958 is shown in Figure 5. This eleven-year period shows a steady rise of between 4 and 5%/yr. Such costs can be expected to increase by the 4% rate for the next five years. Maintenance costs include both materials and labor.

Depreciation for a 1959 plant remains constant. For a plant to be built in 1964, such charges will be 28% higher, reflecting the 5% rate of construction costs. General plant overhead, laboratory, research, sales, and similar costs should increase at between 3.5 and 4.0%, or about 3.75%/yr. Such miscellaneous charges as supplies, packaging, taxes, and insurance are expected to follow the inflation trend of 1%/yr.

Freight rates, in general, have been rising at a 5% rate (Figure 6). Allowance for freight, when applicable, is expected to increase at a rate of 5% annually for the next three years, and 2% for the last two years. This gives an over-all five-year increase of about 20%.

Sample estimate

A simplified production-cost estimate for hypothetical chemical intermediate, Poly-X, is shown in Table 2. An 11.2¢/lb. production cost is estimated under today's conditions. Only one raw material is used in its manufacture, accounting for 45% of the total manufacturing expense. Labor and utilities are roughly 10% each; depreciation, 15%. An average freight allowance is included, but no royalties or license fees are paid. Sales expenses for this bulk chemical are estimated at 0.2¢/lb.

The middle column in Table 2 lists the five-year factors as derived from the annual growth rates previously examined. These are the annual interest rates, compounded yearly for five

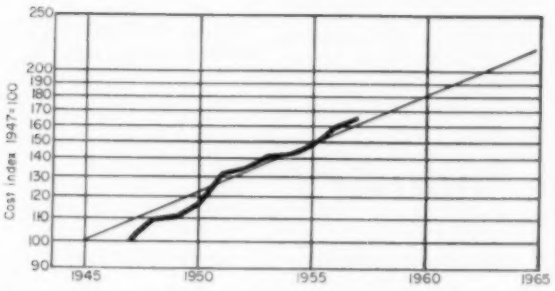


Figure 5. The index of plant maintenance costs for the 11-yr. period shown has risen steadily.

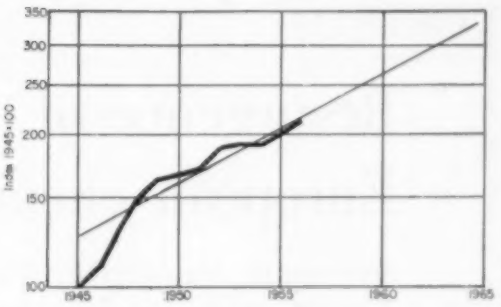


Figure 6. Freight rates have been rising at about 5%/yr.

years, and converted to a decimal factor. This technique is valid, since in most cases a straight-line trend analysis was deemed of sufficient accuracy for this particular purpose. Multiplication of the individual 1959 cost elements by their respective cost factors results in the 1964 costs in the right-hand column. In this instance, a 15% increase for the five-year period is indicated; a rate of about 3%/yr.

In the case of Poly-X, about 65% of the increase is expected to come from raw material costs and labor. This situation should hold true in most cases, since these items generally account for at least 50% of manufacturing costs. No change is indicated for depreciation, since it is a fixed item.

Although it is informative to examine changing costs alone, the effect of such changes on the profit and return on capital employed is usually interesting only to top management. The left-hand column in Table 3 examines the current conditions. At a price of 17¢/lb. of Poly-X, the return is 17%; the payout-time, a little under four years. The investment figures are in ¢/lb. of annual capacity.

Cziner

Copulsky

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With the plant built in 1959, the 1964 costs will yield a lower profit, a return of only 12%, and a payout of just under five years. Of course, the supply-demand-price forecast for Poly-X assumes no change from 1959. This may not be the case with most chemicals. They can be expected to sell at either a higher or lower average price during 1964. The slight increase in the working capital is due to the generally-forecast rise in most costs.

The effect of postponing a decision to build a Poly-X plant today is also shown in Table 3. The capital requirements should be about 27% higher. The 1964 manufacturing and sales costs will increase, due mainly to a higher per-pound rate of depreciation. The return is cut to 9%; the payout-time, extended slightly to 5.5 years.

It may be practical to take only a few key cost factors into consideration. These may prove sufficient for a particular case to give satisfactory results. It is important to recognize that these dynamic forecasts are applicable for both rising and declining cost trends, for periods of inflations and depressions.

Table 2. Poly-X production costs, ¢/lb.

	1959	5-yr. Factors	1964
Raw materials	5.0	1.16	5.8
Labor	1.0	1.28	1.3
Utilities			
Gas	0.1	1.17	0.1
Steam	0.5	1.17	0.6
Water	0.2	1.05	0.2
Electricity	0.3	1.05	0.3
Maintenance	0.7	1.22	0.9
Supplies and packaging	0.3	1.05	0.3
Laboratory	0.1	1.20	0.1
Plant overhead	0.5	1.20	0.6
Taxes and insurance	0.3	1.05	0.3
Administration	0.4	1.20	0.5
Depreciation	1.5	1.00	1.5
Freight allowance	0.3	1.20	0.4
	11.2		12.9
Sales expenses	0.2	1.20	0.2
	11.4		13.1

Table 3. Poly-X profits, ¢/lb.

	1959	1964	1964 Plant
Plant investment	15.0	15.0	19.2
Working capital	1.5	1.7	1.8
Investment	16.5	16.7	21.0
Production and sales costs	11.4	13.1	13.5
Price of Poly-X	17.0	17.0	17.0
Profit: pre-tax	5.6	3.9	3.5
post-tax	2.8	2.0	1.8
Return on investment	17%	12%	9%
Payout-time, yr.	3.8	4.8	5.5

Forecast perspective

Cost and price forecasts are based on assumptions, opinions, projections, correlations, and guesstimates. It is experience and a good business sense which give them their real significance. Any experienced practitioner of the art of forecasting will be frank to point out that a ± 20%-reliability range is very good. Anything better is usually luck. A long-range forecast serves a useful purpose, even if it only correctly indicates the *trend*.

In effect, then, in dynamic-cost forecasting, the art of forecasting is added to the art of estimating costs. The combined reliability will depend on the accuracy of both techniques. As long as the chemical manager recognizes the inherent limitations of forecasting as well as he understands the accuracy of cost estimating, long-range cost estimates can become a very useful tool. Like any evaluation, they should be reviewed and adjusted periodically.

The estimation of future costs can give management a dynamic insight into the factors which make up the cost of a product.

DUANE M. FEELEY
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Resurgence of European chemical industry

Increasing competition from the revived chemical industry of Europe means double trouble for U. S. industry. Internally within Europe, American chemical exporters will face shrinking markets. Elsewhere the Europeans will present sharply increasing competition.

A COUPLE OF YEARS ago, a vice president of Arthur D. Little said that it would not be too long before the majority of our market studies would, of necessity, have to include consideration of international as well as U. S. markets. This prediction is coming true. The chemical industry is growing throughout the world, and in many areas, particularly in Europe, it is growing more rapidly than in the United States. European economies have recovered sharply since the end of World War II. Since 1950, the total industrial output of the six European countries comprising the major part of the European Common Market has increased 76%, while the U. S. output has increased 27% in the same period. The combined population of these six countries (Belgium, France, W. Germany, Italy, Luxembourg, Netherlands) is approximately the same as that of the United States, but their Gross National Product is roughly half that of this country. In addition to the Common Market, a new alliance of seven European countries, the so-called "outer seven," which consists of England, Norway, Sweden, Denmark, Austria, Portugal, and Switzerland, comprises an area containing 90 million people with a Gross National Product of about 90 billion dollars. This new European alliance is scheduled to come into being soon, when the agreement is ratified by all the participating countries.

The Common Market countries are important producers of chemicals and, using 1953 as the base year, their chemical industry is growing at a rate roughly twice as fast as that of the U. S. chemical industry.

Key individuals concerned with the international chemical scene discussed this situation at a seminar sponsored by A. D. Little and demonstrated that the U. S. chemical industry is vigorously moving into the European Common Market and the "outer seven" areas. U. S. firms see a reasonable repetition of U. S. experience in large markets, free movement of trade, and some external protection. They are relying on U. S. know-how in large-scale production and mass merchandising as major advantages in this market. A number of companies are moving into these areas to protect export markets that could, and probably would, be satisfied by local industry if they did not make such a move. Thus, the consideration of foreign chemical markets and the influx of products made in foreign countries are looming larger when new projects are being considered. The chemical engineer conducting market research will be called upon more and more to be knowledgeable in this area.

The future of all chemical engineers here, whether in market work or not, will be indirectly, and perhaps directly, affected by the rapid expansion of the chemical industry in Europe, either because of the activities of American firms abroad, or because of increasing competition from European firms in the U. S. and foreign markets now served by American firms.

INDICES OF CHEMICAL SIZE AND GROWTH IN EACH COUNTRY VS. THE U. S.

	Belgium Luxembourg	France	Germany, Western	Italy	Netherlands	United States Chem and Allied Prod.	United States Industrial Chemicals
1953	100	100	100	100	100	100	100
1954	117	-	-	126	110	101	100
1955	127	-	-	143	117	114	120
1956	136	152	140	148	123	121	127
1957	141	176	157	154	133	125	133
'57 Sales (millions of $)	520	3210	3910	2030	530	25,400	

Source: The Chemical Industry in Europe, OEEC, January 1959. U.S. data from Survey of Current Business, U.S. Department of Commerce

ROBERT W. SCHRAMM

. . . . *Chemical economics*

A tool in market analysis

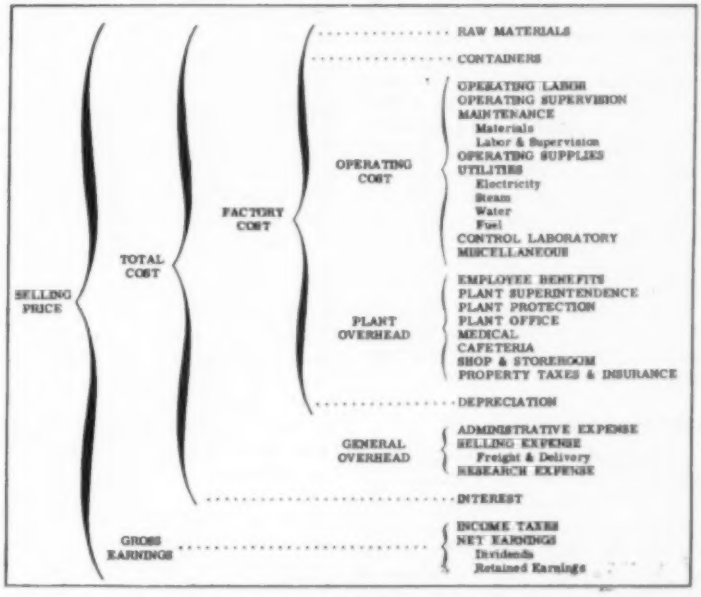

Figure 1. The selling price must take into consideration these many and diverse costs.

As BUSINESS PLANNING begins to delve into the questions of profitability, break-even and the effects of a delay in plant start-up or market development, chemical engineering economics and chemical marketing analysis will in time find themselves welded together. This will be because of the integrated business studies that will be necessary for the improvement of existing products, the introduction and commercialization of new products, and the location of plants to serve the markets for either existing or new products.

The potential profit from a new project must be related to the investment of both time and money in a way that will conform with the objectives of the company. The relationship between investment and the likelihood of success must be established as early as possible. Research like almost everything else is becoming more costly. It has been the contention that new product projects should have their engineering economic evaluation started long before they reach the pilot plant stage (*1*). Market studies can be used to point out the most profitable market and shorten the development time and expense required to reach them commercially. And oftentimes a relatively small amount spent on market analysis can save expenditures of many thousands of dollars of research funds that would have been spent developing technology or products that were unmarketable.

There are many cases where a product or process has flopped not because it did not produce but because the market would not support the product. Any company with a fair amount of operating experience has a few of these tucked away in its skeleton closet. They are rarely brought out for public view. However, at a recent American Chemical Society meeting (*2*) a number of these cases were exhibited for review. In these stories there was only one product whose main trouble was in the technology. In all the others the failure of the product was in the marketing.

This article will not discuss how to improve market analysis in cases such as these but how chemical engineering economics can join with market analysis to help to establish some of the parameters in a market. It will touch briefly on four subjects:

1. Setting a selling price
2. Make or buy decisions
3. Sizing a plant
4. Locating a plant

and then conclude with a brief hypothetical case on an application.

What's the price tag?

When a selling price is set on a chemical, by necessity this price has to cover all the expenses and materials that have gone into the production of the product, as well as providing for earnings which will pay income taxes and net earnings to pay dividends and to plow back into the business, Figure 1.

In many studies you will want to know the contribution which each item makes to the total cost or selling price. In a comparison of alternate

processes on an over-all basis, significant differences might be lost unless the costs are broken down step-wise. You can spot the items that might be changed or improved to advantage. This method of analysis is especially convenient for trying to balance out such things as increased investment against a saving in labor and how production costs will vary with the scale of operations (*3, 4, 5, 6*).

In the field of marketing the exclusion chart can be used as a general shortcut for quick pricing of a product. This is entirely an empirical relationship showing the price at which a product must sell if it is to enjoy commercial success in a competitive market. The procedure is to take known products selling in the market and plot quantity of production against their price. This then gives a relation that shows that unless a product of a given type can be provided for less than a certain price, for example 28¢ a pound or below for cyclic intermediates, it is excluded from enjoying a market above 3 million pounds a year. One particular exclusion chart was prepared by Herman Zabel of Roger Williams, Incorporated (*7, 8*).

Make it or buy it?

An area which always involves engineering economics is make or buy decisions. A company cannot be too thorough in its evaluations. The main criterion usually is the return on investment. In times past a shortage of raw material has led many companies to consider an integration on the basis of "Damn the cost, we need the material." However, the best situation would be where the return on investment is at least as good as the return of the most efficient producer and at worst equal to the average of the industry, but in no case should it be lower than the yield of current operations to the company.

Essentially this is the balancing of the production of a given raw material against the use of the money in other projects that may be available. The volume should be large enough to justify an economic production unit. Often the total requirements of the company are such that it could consume the output of a minimum-sized plant. However, because of scattered consumption points within the company, such a decision is not logical because the freight and handling costs of the material would reduce the return on investment to an unattractive level.

These decisions should be viewed not solely from the engineering economics involved but also from the marketing analysis, whether present suppliers may become competitors because of your decision to produce, and a study of the competitive position that you would enjoy if such became the case.

How big a plant?

The consideration for sizing a plant for growth is becoming one of continuing interest. It is becoming more and more the policy of the chemical industry to build excess capacity so as to maintain position in the market place. However, some plants can turn out to be white elephants. The oversizing of plants obviously is better suited for maintaining position in large volume, well-established chemicals rather than for new products whose markets depend to a great extent upon the development activities that are yet to come. It is also quite obvious that some degree of risk must be faced in any project and the more over-capacity that one has, the more risky the entire venture becomes.

It is not only the case of the plant that is being sized for growth, it may be a determination between the cost of carrying inventories to meet seasonal demand and sizing a plant to be able to meet the peak demand. The extent to which new facilities can be minimized or balanced may have very important cost ramifications. Sizing of the plant more often becomes one of the economics of marketing rather than of engineering economics.

There have been several studies made on sizing of a plant and how one would approach it. Jim Weaver has published (*9*) an analysis chart which is an excellent example of utilizing a plant on a given manning schedule rather than scheduling the plant for around-the-clock operations. This, of course, applies only in the operation of plants that operate noncontinuously or that can be started up and shut down without having a great amount of off-specification material and without causing undue damage to the process equipment.

In the operation of continuous plants it appears (*10*) that the setting of a minimum rate of return by the company and a determination of the variable cost of the product seem to set the number of years in the future for which one can economically build plant capacity regardless of the anticipated growth.

Where to put it?

Marketing has more and more come to play a determining part in the location of a plant. Increased transportation charges on both raw materials and finished goods have made it necessary to pay closer attention to plant location. The idea of the variance of production cost or marketing with transportation cost is not new to the chemical literature (*11*). The marketing considerations have slowed down plans such as have often been proposed in the past where any refinery having a capacity of 25,000 barrels a day was a potential site for a 100,000-pound ethylene plant for a petrochemical operation.

Because of the growing inter-relation between new methods of transportation and new modes of delivery,

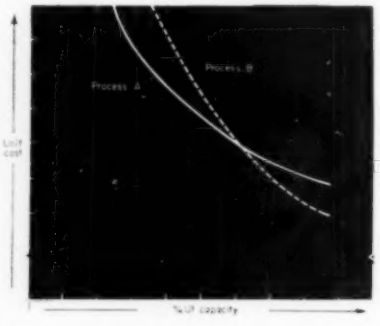

Figure 2. Unit cost versus volume can affect decision as to which process to use.

markets must be continually analyzed as to possible cost savings and new competitive situations.

The coming of the 20,000-gallon king-sized tank car, the increasing importance of water transportation, the use of collapsible rubber containers to transport bulk liquid and plastic materials, and systems like the recently inaugurated sodium carbonate slurry, are all factors in somebody's market.

There have been propositions to establish chemical pipelines (*12, 13*) to handle chemical products in the same manner as gasoline and other petroleum stocks have been handled for years. An early study of this (*14*) showed that a market in excess of $70 million might be opened up by the building of petrochemical plants in the midwest rather than in the southwest. These and other similar developments with their market implications have effects which are economic in nature.

Making a case

Assume for the moment that you have two new processes, Figure 2, for the production of phenol. Process "A"

calls for the oxidation of liquid benzene by means of ozone at low pressure, moderate temperatures, using uranium oxide as your magic catalyst, and in Process "B" you have a new dehydrogenation catalyst that will allow you to catalytically dehydrogenate cyclohexanol or cyclohexanone. In any case, you have the new processes and want to know where they will stand in the market place.

Obviously, a market analysis of a standard product such as phenol can be made with relative ease. Most conditions of the market can be judged. The problem that remains for you is the determination of whether you can be competitive in the market, maintain or lower prices, and produce a satisfactory return on the investment for your company with an eagle eye to the probability that present producers may bring pressure to bear.

Your market survey as to where producers of phenol are located shows that the greatest number of plants are the coal tar ovens but that they produce only 0.3% to 0.7% phenol for each pound of coal tar produced and in total they represent less than 5% of the total production. You then list the benzene sulfonate plants, the chlorobenzene-caustic plants, the chlorobenzene Raschig plants, and the cumene plants.

You then study the plant location and process to try to get at the competitive economics. Does a sulfonation plant have low cost sulfuric acid and caustic available? Is there a convenient outlet for the sodium sulfate-sodium sulfite by-product? Do the chlorobenzene-caustic plants have captive and/or low cost chlorine? Is the local requirement such that heavy freight equalization is not necessary to move the large volume required to justify the continuous Raschig plants? An adequate acetone market and the markets for acetophenone and methylstyrene are important to the cumene plants. With these things determined, you can see if your processes have the production economics necessary to compete.

Assuming Process "A", the following case was set up:

1. The payout would be figured against the plant investment and not include working capital.
2. A five-year payout from the time of the start-up of the plant would be the maximum acceptable time.
3. The minimum acceptable return would be that the plant operations meet all of its own expenses, depreciation charges, taxes, interest charges, and sinking fund payments over the five-year period.
4. The plant would be sized to have a capacity of 2 million pounds a month.
5. Raw material per pound of produced product is constant regardless of the percentage of capacity of operations.
6. The other charges for operations other than those of raw materials would be fixed regardless of the percentage of capacity.
7. Depreciation would be on a straight line 10% basis.
8. Sales, administrative and research overhead expenditures would each be 5% of sales.
9. The full fixed asset cost of the plant would be paid off in five years with a payment of 20% made each year end.
10. Interest on the borrowed money would be 6% of the unpaid balance. This 6% rate on the unpaid balance of a five-year liquidating note would average 1.8% of the total amount over the five-year life of the note.—Accountants Handbook
11. Federal income taxes would be 52%.
12. Depreciation money would be used for debt retirement.

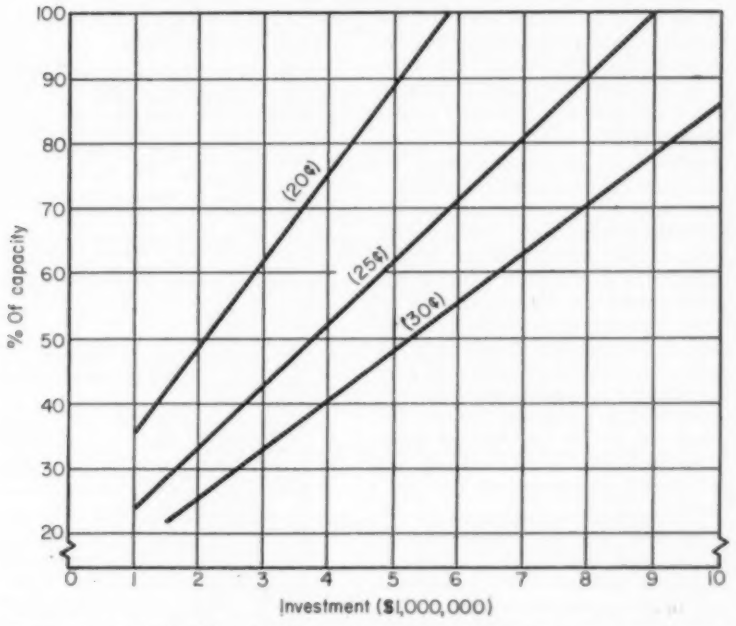

Figure 3. Relationship of selling price, percent capacity, and investment.

It is now possible to start the calculations. To do this, you will have,

C = Capacity of the plant = 24×10^6 lb.
p = Percent of plant capacity sold
R = Net realization = dollars per pound
G = General overhead = (100 − a − s − r) where
  a = administrative expense as percent of sales = 5%
  s = sales expense as percent of sales = 5%
  r = research expense as percent of sales = 5%
m = Raw Material and Containers = $0.0675/lb.
f = Fixed cost = plant overhead = $540,000 yr.
I = Investment
P = Payout in year = 5 year
d = Depreciation rate percentage = 10%
t = Net income after tax rate percentage = 100 − 52 = 48%
i = Interest rate adjusted to average annual percentage = 1.8%

$C \times p \times R$ = Total Income
$G \times C \times p \times R$ = Income after general overhead
$(C \times p \times m) + f$ = Cost of goods sold

Subtracting;

$(G \times C \times p \times R) - (C \times p \times m) - f =$ money available for:
  interest charges
  depreciation
  income tax
  net income

I/P = Average annual cash generation required

Id = depreciation throwback

$(I/P-Id)$ = Average annual after tax net income needed

$(I/P-Id)/t$ = Average annual before tax income needed

Ii = Interest charges

$(G\times C\times p\times R)-(C\times p\times R)-f=(I/P-Id)/t+Id+Ii$

Substituting, you get;

$$I = \frac{24\times 10^6\times p\times R}{0.326} - \frac{(\$0.081\times 10^6\times p)-\$540{,}000}{0.326}$$

Since it is usually possible to have an available cost for a given plant size you may substitute the plant cost for I and if your market analysis has shown you how the anticipated market development may take place in quantity, it is possible to solve for p = the percentage of operation which in turn will give you the price that is required to meet the conditions that have been set up.

The percent of capacity of operations is an average figure for five years of operation. If, for example, you have estimated that the plant would operate at 45% of capacity the first year, 50% the second, 60% the third, 70% the fourth, and 80% the fifth, the average would be 65% for the five years and would be the figure to use with the chart.

It should be realized that while this chart, Figure 3, is on an average basis that if in the early years of the plant operation it were below the break-even point and this were the only operation of the corporation, then a different situation would apply because of the loss recoupment that would be possible in the tax-loss carry forward in the profitable years. The principal effect of this would be the requirement of a much higher percentage of operation in the latter years.

A similar chart could then be made for Process "B" and it might show that while unit costs were greater at lower capacities, the accumulated profits were bigger because of increased earnings at higher volumes.

This plan may also be used as a form of an exclusion chart which would show what could be paid for the fixed assets of the plant at varying capacities.

On new products, if you have estimated plant costs and an average expected market development rate, it is possible to determine at what price the product will have to be sold to meet your profit requirements. This may be determined for alternative processes. These prices then can be compared to the proper exclusion chart to see if they fall within the inclusion area of volume and price. If they do not, then you either have to be satisfied with a lower profit, realizing your vulnerability to a declining price or simply not enter the business unless your new product has unusual properties which will allow it to have some very specific uses for which the customer is willing to pay a higher price.

While most of the discussion has concerned itself with the evaluation of new capacity or the sizing of a plant and price setting for a new product, most of the information is equally valuable in determining when operations should be discontinued or at what capacity present facilities will have to be operated at various prices to yield a satisfactory return. At least one study has been published about discontinuing operating units (*15*) which the market analysis has shown to be declining. This in essence, is a variation of the break-even chart.

The break-even chart (*16, 17, 18*) is the most clear and concise way for the engineer and market analyst to synthesize and see clearly a great volume of data as to price variance, minimum sales, and profit potential required for a given plant size.

These techniques are used not only in a market but in national studies (*19*) which have integrated into the study labor costs, their possible fluctuations, the location of markets, the variance of different factors as to whether they are high or low investment industries, and the various price and consumption levels.

It is even possible to bring the game theory into use in determining the size of a plant and whether it is best to build a small plant or a medium plant with expansion possibilities or other alternatives. These have been studied in one published (*20*) hypothetical case. While it is known that there has been some use of this as a tool, no actual cases have appeared in the literature nor is it expected that they will for some time.

The challenge of the decade of the sixties to the chemical industry has already been made. Population is certain to be growing, and as natural resources steadily decline in quantity and quality, it is expected that chemical technology will be looked upon to feed, clothe, shelter, maintain, and defend the population through the production of plastics, synthetic fibers, fuels and rubbers, the harnessing of nuclear and solar energy, the improvement of renewable resources and the development of reclaiming processes. Chemical engineering economics is certain to be an indispensable tool in the analysis of these future markets as they develop.

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1-Computer control of processes . . .

. . . Mathematics is the key

Economic justification and equipment availability still leave many technical problems to be solved.

Engineer operates an IBM Tape Reader in conjunction with IBM 1620 computer.

THERE HAS BEEN considerable speculation recently as to the possibility of the computer control of chemical processes. The implementation of such control, however, presents many difficult and intriguing technical problems, aside from the economic justification and the hardware required. This article outlines some of these problems and reports on a research program to investigate the measurement and computational requirements for achieving such control.

Conventional process control design

Consider the simplest possible situation, a process with a single input and a single output. The output (temperature) $c(t)$ is to be maintained at some desired value by changing the input variable (steam flow) $u(t)$. The classical approach to such a problem is indicated in Figure 1 with the following comments:

a. The actual output of the process is determined by physical measurement and converted into some convenient form such as electric voltage or air pressure.

b. The *desired process output* (set point) $r(t)$ is compared with the actual process output $c(t)$ to give the *error signal.*

$$e(t) = r(t) - c(t) \qquad (1)$$

c. The low-power error signal is converted by the controller into a high-power electric or pneumatic signal which actuates a transducer. In a simple case, the controller may be simply an amplifier or it may incorporate **rate** (derivative) and **reset** (integral) action as well.

d. The transducer converts the controller output into a physical quantity which directly affects the process. Thus, the transducer may be an electric, hydraulic, or pneumatic valve-positioner which changes the flow of steam to the process.

In engineering such a system, the process, the means of physical measurement, and the transducer are usually given (or are selected from) a small number of possibilities. The job of the control system engineer is then to design the controller. *This task frequently entails little more than determining whether or not certain available types of controllers will do the job.* For instance, in the simplest case the controller may be an amplifier which has one adjustable parameter, the gain. The gain required for meeting the performance specifications of the system (for instance, the steady-state error, which is roughly inversely proportional to the gain) may be such that the over-all system will be unstable. In this case, the controller must be modified to stabilize

. . . in carrying out the design steps it is generally taken for granted that the dynamic characteristics of the process will change only slightly . . .

the system. In general, one starts out with a simple configuration and then modifies it until the desired performance specifications are met. There are many ways in which this (essentially trial and error) procedure may be improved but these need not be discussed here.

The ability to obtain the necessary physical measurements on the input and output is assumed in this scheme and in all subsequent discussion. While this may, in itself, represent a serious problem, it will be assumed that such measurements are always possible.

Digital control philosophy

If a digital computer is to be used as part of the control system a different approach may be made. Instead of having any preconceived notions about what the controller should be, the following question may be asked:

What must be the input $u(t)$ to the process at any instant of time and under any circumstances to achieve the desired output $c(t)$?

This is essentially the same question facing the manual operator whose job is to manipulate $u(t)$, (the valve opening in the previous example). More specifically, to instruct a computer about how to change $u(t)$ from time to time, it is necessary to have three different types of information.

a. It is necessary to specify the desired behavior of the process. This is essentially a management, not an engineering decision. For instance, one may wish to optimize quality, throughput, gross profit, etc.

b. It is necessary to know what happens when a known input $u(t)$ is applied to the process. This is equivalent to knowing the process dynamics. Such information can be obtained with adequate accuracy only by actual physical measurement.

c. Since it is impossible to have identically-zero error $e(t)$ (deviation from desired behavior) at all values of time, there must be available some measure of the "badness" of the error when it is not zero. This is called an error criterion, or loss function. Error criteria are subjective; they are largely arbitrary and depend on the particular type of process controlled and on the preference of the designer.

Advantages and disadvantages

For the rest of this discussion, it will be assumed that the computer in question is a general-purpose digital computer. The chief advantages of a digital computer are flexibility and adaptability. It is not necessary to specifically design a digital computer for a particular control job, it is only necessary to program it.

In carrying out the design of a control system according to the principles outlined in subsequent sections, one is led to a number of mathematical equations. These equations can always be reduced to a series of arithmetic operations—or better still, they can be derived with this objective in mind at all times. Regardless of what these arithmetic operations are, the digital computer can be programmed to solve them—provided that it has sufficient speed and capacity for storing numbers and instructions. The role of many different pieces of equipment (amplifiers, corrective networks, integrators, etc.) is taken over by the digital computer. Since the digital computer can perform the required operations with practically infinite accuracy and repeatability, hardly any "hardware" problems arise, and the design of the overall control system can be considered essentially complete once the program for the digital computer has been specified. Much of the know-how in any digital-computer controlled system will be incorporated in the program.

A decisive advantage of using the digital computer for control over present-day procedures is that in carrying out the necessary design steps, it is generally taken for granted that the dynamic characteristics of the process will change only slightly under any operating conditions encountered during the lifetime of the control system. Such slight changes are foreseen and are usually counteracted by using feedback. Should the changes become large, the control equipment, as originally designed, may fail to meet the performance specifications. By contrast the computer can repeat the sequence of calculations leading to the "best" choice of $u(t)$ at any time. Such a control system then operates always at, or near, the optimum conditions,

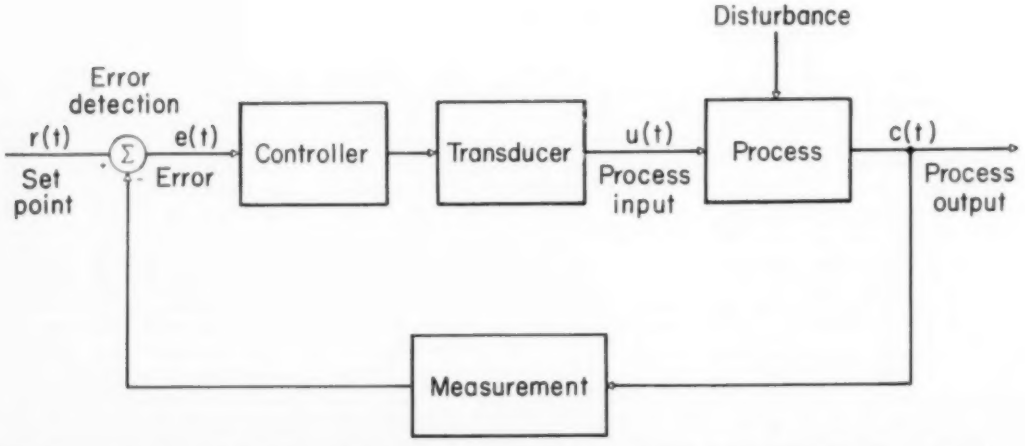


Figure 1. Conventional control arrangement for the simplest possible situation of single input and single output.

provided only that changes in the dynamic character of the controlled process do not occur more rapidly than the speed with which the computer adapts itself to changes in its surroundings. This may be considered an extension of the feedback principle. More will be said later concerning this feature of digital control.

The principal disadvantage of a computer-controlled system stems from the flexibility of the digital computer, which is an expensive and complicated device. Particular attention must be paid to operating a computer-controlled system in an optimal fashion. There must be considerable improvement in performance over conventional control systems to justify the added cost and complexity. This points to uses in large plants such as in the chemical industry, where over-all control is mainly manual for various reasons; or to fast processes, where manual control is insufficient. Moreover, computer-controlled systems require more refined methods of engineering (in the sense of specifying a relatively sophisticated program for the digital computer) and much attention must be paid to matters which in conventional systems (due to limited flexibility) have to be overlooked, but which significantly affect the overall performance of a complex system.

Sampling

Because a digital computer is a machine that operates with numbers, it cannot directly accept information which is a continuous function of time, such as the voltage from a thermocouple, or the pressure from a flowmeter. For this reason, continuous physical measurements must be converted into numbers in some fashion. This operation is called sampling. An instant of time when a measurement is converted into a number is a *sampling point;* the corresponding number, a *sample*.

No matter how often one samples, some information is always discarded in the process. However, this loss is often insignificant. In fact, if the signal $x(t)$ to be sampled can be presented in this form.

$$x(t) = \sum_{n=-N}^{n=N} a_n e^{int}$$

where $i = \sqrt{-1}$

then it can be shown that the following is true.

> **Sampling Theorem:** If the average number of sampling points/unit time is greater than $N\omega/\pi$ (greater than twice the highest component frequency of the signal $x(t)$) then the original signal $x(t)$ can be reconstructed as accurately as desired from the samples
>
> $x(t_0), x(t_1), \ldots, x(t_k)$
>
> provided one is willing to wait for a sufficiently long period of time.

In less precise language, the sampling theorem says that the behavior of a "smooth" function between sampling points can be always reconstructed with arbitrary accuracy by means of some scheme of delayed interpolation, provided one knows the values of the function at a large number of sampling points. Note that the sampling theorem does not require that samples must be taken in a uniform pattern. In practice, however, it is often most convenient to sample periodically, so that the sampling points are given by

$$t_k = kT; \quad k = 0, 1, 2, \ldots$$

where T is called the *sampling period;* the integer k refers to the k-th sample.

Whether sampling is introduced into a control system deliberately (to use a digital computer for control purposes) or unavoidably (when a measurement on the process is represented by a physical sample, which is analyzed in the laboratory), the result is a sampled-data system. In view of the sampling theorem, it is intuitively obvious that sampled-data systems need not be inferior to systems in which there is no sampling.

If the sampling operation takes place more rapidly than the changes in the process behavior which the control system is designed to counteract, then sampling does not impose a serious limitation on the over-all system. For instance, the desired sampling rate depends primarily on the dynamics of the process to be controlled.

Chemical process dynamics

There are many ways in which the dynamic behavior of a physical system can be described. In analytical studies, one frequently uses ordinary or partial differential equations; in numerical calculations, difference equations. Some insight into the advantages and disadvantages of these methods of representation may be gained by examining more closely the fundamental concepts involved in the study of dynamic systems.

The first important concept is the notion of the *state of the system*. This is defined as follows: At time t_o, the state of the system is the least amount of data (usually a set of numbers) from which the behavior of the system can be uniquely determined for all $t \geq t_o$, provided that all external influences (inputs) acting on the system are known for all $t \geq t_o$. In other words, the information incorporated in the set of numbers representing the state of the system is all that one has to know about the past evolution of the system to predict the future evolution of the system. In intuitive physical terms, the state specifies the energy stored up in the system at time t_o as a result of past inputs.

The second important concept used in the study of dynamic systems is the *state-transition function*. The evolution of the dynamic system in time may be visualized as continually passing from one state to the next; the state-transition function specifies how the state of the system evolves from one instant of time to the next.

Two simple examples will illustrate these notions.

(a) Consider a single-pipe heat exchanger with fluid inside the pipe and condensing steam outside and let

c	=	heat capacity of fluid = constant
h	=	heat transfer coefficient between fluid and wall
L	=	total length of pipe
r	=	radius of pipe
t	=	time
T_w	=	temperature outside wall of pipe = constant
$T(x, t)$	=	temperature of bulk fluid as a function of x and t
V	=	fluid velocity = constant
x	=	distance down pipe measured from inlet
ρ	=	fluid density = constant

From a heat balance over and infinitesimal section, Δx, of the pipe, the following partial differential equation results

$$V\frac{\partial T}{\partial x} + \frac{\partial T}{\partial t} = a(T_w - T) \quad 0 \leq x \leq L \quad (2)$$

where $a = 2h/r\rho c > 0$. A boundary and an initial condition must be added

. . . What is important is that it should be easy to adjust the model to match the actually measured behavior of the physical system . . .

to obtain a particular solution of Equation 2. These are

$$T(x, t_o) \quad \text{for } t = t_o, \quad x \geq 0$$
$$T(0, t) \quad \text{for } t = \geq t_o, \quad x = 0 \qquad (3)$$

From the preceding discussion, it is clear that the function $T(x,t_o)$ represents the state of the system; in fact, it is the density of stored thermal energy along the length of the pipe at time $t = t_o$. The second function, $T(0,t)$ represents the temperature of the entering fluid. This is the input to the system. Because the fluid is assumed to move with a constant velocity, the input may be represented by the temperature profile of a fictitious, infinitely long section of the pipe which corresponds to the negative values of x. Thus

$$T(0, t) \equiv T[-V(t-t_0), t_0] \quad t \geq t_0 \quad (4)$$

and now the function $T(x,t_o)$ (defined *for* $-\infty < x \leq L$) contains all the information necessary to predict the behavior of the system, within the idealizing assumptions made.

The state transition function indicates how to find $T(x,t_1)$ as a function of $T(x,t_o)$ (the state and the input) at any instant t_1 after t_o. To obtain the state transition function, the differential Equation 2 (the differential equation is simply a way of specifying the state transitions) corresponding to the infinitesimal change in time $t \rightarrow t + dt$ may be solved to yield, by elementary methods,

$$T(x, t_1) - T_w = [T(x - V(t_1 - t_0), t_0) - T_w]e^{-a(t_1 - t_0)} \qquad (5)$$

This equation shows that the profile of the temperature difference $(T(x,t) - T_w)$ travels down the pipe with a velocity V and is attenuated by the factor $e^{-a(t_1 - t_0)}$. To obtain the state-transition function ϕ, add T_w to both sides of Equation 5:

$$T(x, t_1) = \varphi[t_1; T(x, t_0); t_0] = [T(x - V(t_1 - t_0), t_0) - T_w]e^{-a(t_1 - t_0)} + T_w \qquad (6)$$

(b) As a second example, consider a simple chemical reaction scheme of A plus B reacting to form C in a perfectly mixed isothermal reactor. The input flow rate, containing reactants A and B, and the output flow rate, containing A, B, and C, are taken as equal. Assuming that the rate of reaction depends only on the product of the concentrations of the reacting molecules, a material balance on each component yields

$$\frac{dx_A}{dt} = -kx_Ax_B + \frac{F}{V}u_A - \frac{F}{V}x_A$$
$$\frac{dx_B}{dt} = -kx_Ax_B + \frac{F}{V}u_B - \frac{F}{V}x_B$$
$$\frac{dx_C}{dt} = kx_Ax_B - \frac{F}{V}x_C \qquad (7)$$

where x_A, x_B, x_C are the respective concentrations of the various compounds in the reactor, u_A, u_B are the concentrations in the feedflow, F is the flow rate through the reactor, V is the volume of the reactor, and k is the reaction rate coefficient.

Given the input concentrations u_A and u_B, it follows that the system of differential equations has a unique solution determined by the values of the concentrations x_A, x_B, x_C at time t_o. The concentrations $x_A(t_o)$, $x_B(t_o)$, $x_C(t_o)$, (by an old fashioned and misleading, but well-entrenched terminology) are called the initial conditions; in the present language, they are simply the state of the system at time t_o.

To find the state transition equations, it is necessary to solve the differential Equations 7. Because they are nonlinear (see later comments), this cannot be done directly, but the solution can always be found by numerical computation or by observing the behavior of Equations 7 on a physical analog, such as an analog computer.

In any event, the complete set of solutions may be written in the form, assuming $u_A(t) = \text{constant}$, $u_B(t) = \text{constant}$,

$$x_A(t_1) = \varphi_A[t_1; x_A(t_0), x_B(t_0), x_C(t_0); u_A(t_0), u_B(t_0); t_0] \qquad (8)$$

To avoid having to write down many equations in a cumbersome fashion, it is very convenient to use vector notation. Thus, $\mathbf{x} = (x_A, x_B, x_C)$ will stand for the three numbers denoting the concentrations; $\mathbf{u} = (u_A, u_B)$ and similarly $\mathbf{f}$ and φ will stand for the three functions of the three variables x_A, x_B, x_C which are defined by Equations 7 and 8 respectively. Equations 7 and 8 may now be written as

$$\frac{d\mathbf{x}}{dt} = \mathbf{f}(\mathbf{x}, \mathbf{u}) \qquad (7')$$

and

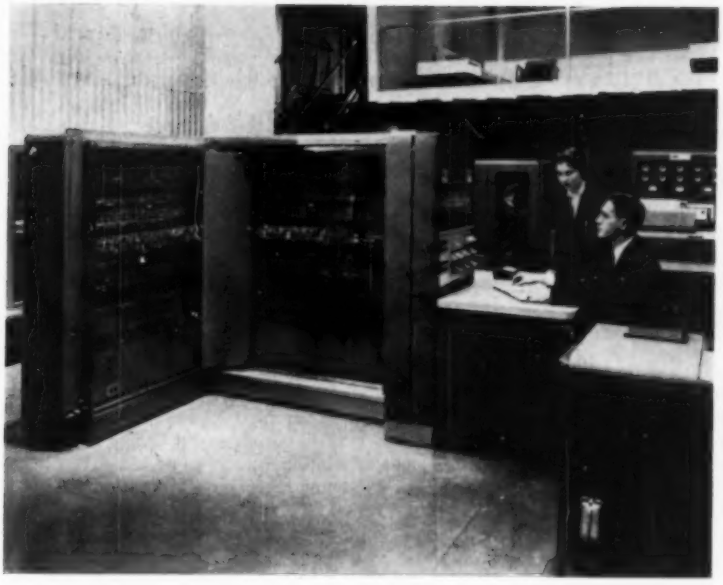
$$\mathbf{x}(t_1) = \boldsymbol{\varphi}[t_1; \mathbf{x}(t_0); \mathbf{u}(t_0); t_0] \qquad (8')$$

The function φ in 8′ is the state transition function. Given the state at time t_o, it shows what the state will be at any later time t_1, assuming the input $\mathbf{u}(t_o)$ is constant during the entire time interval (t_o, t_1).

It should be noted that the differential Equations 7 play only an intermediary role in the determination of the state transitions. It happens that, physically, it is easier to postulate the mechanism of infinitesimal state transitions, *i.e.*, to derive the differential equations. But practically, this may not be convenient because one is then stuck with the none-too-pleasant task of having to obtain the finite state transitions by *solving* the differential equations.

Similar equations are obtained in other cases of engineering interest, provided the derivation is based on writing mass and heat balances for various "lumped" elements of a system. By considering mass and heat balances over infinitesimal volumes, partial differential equations frequently result. The use of partial differential equations, however, is frequently avoided in control systems in favor of *sets* of ordinary differential equations. This is because of the much greater mathematical difficulties of simulating and/or solving the former. Saying that a dynamic system is represented by a partial differential equation is equivalent to saying that the state of the system is a continuous function; replacing the partial differential equation by a set of ordinary differential equations is equivalent to replacing the state function by the set of values of this function at discrete points (sampling in space). This is the real significance of the method of lumping.

A differential equation specifies in



The large-scale IBM 704 Electronic Data Processing System executes most of its high powered operations at a rate of 40,000 a second.

which direction the state transitions proceed from any given state by virtue of continuity. It is possible to assume that this direction remains unchanged over a small interval of time. This means that the differential equation can be replaced by a difference equation, which is then used to compute the state transitions numerically. For a small sampling interval T the simplest numerical integration formula leads to

$$\mathbf{x}((k+1)T) - \mathbf{x}(kT) \simeq T \cdot \frac{d\mathbf{x}(kT)}{dt}$$

k = any integer (9)

Applied to equation (7)

$$\mathbf{x}((k+1)T) = \mathbf{x}(kT) + T\mathbf{f}(\mathbf{x}(kT); \mathbf{u}(kT))$$

or

$$\mathbf{x}((k+1)T) = \hat{\varphi}[(k+1)T; \mathbf{x}(kT); \mathbf{u}(kT); kT] \quad (10)$$

φ is the approximate state transition function over the finite time interval form kT *to* $(k+1)T$.

On the basis of these examples, the following observations may be made:

a. The concepts of state and state transition function are fundamental in any dynamic system, regardless of whether it is described by a partial differential equation, ordinary differential equation, or difference equation.

b. Although the analytic derivation of the dynamic equations may take a variety of forms, in control systems practice the information about the dynamics of the system must be in a readily usable form. It is not important whether or not the model used is one that is easily derived from physical principles. What is important is that it should be easy to adjust the model to match the actually measured behavior of the physical system, and that the model should supply, in a convenient form, the information required for the design and operation of a control system.

The difficulties associated with solving the nonlinear set of equations of the form of 7′ are usually circumvented, as a matter of necessity, by linearizing the model. This is done as follows: Define the *equilibrium* or *steady states* of the process by

$$\frac{dx_1}{dt} = \frac{dx_2}{dt} = \ldots = \frac{dx_n}{dt} = 0 \quad (11)$$

or by

$$\frac{d\mathbf{x}}{dt} = \mathbf{f}(\mathbf{x}, \mathbf{u}) = 0 \quad (12)$$

in Equation 7′. For fixed $\mathbf{u} = \mathbf{u}^*$ the solution of the equation $\mathbf{f}(\mathbf{x}^*, \mathbf{u}^*) = 0$ determines the equilibrium state variables $x^*_1, x^*_2 \ldots$ or $\mathbf{x}^*$ where the asterisk is used to indicate a steady state value. The deviations from this equilibrium state can be denoted by

$\mathbf{a} = \mathbf{x} - \mathbf{x}^*$ = deviations of $\mathbf{x}$ from equilibrium

$\mathbf{b} = \mathbf{u} - \mathbf{u}^*$ = deviations of $\mathbf{u}$ from equilibrium

Expanding $\mathbf{a}$ and $\mathbf{b}$ in a multidimensional Taylor Series, and truncating the series after the linear terms, converts Equation 7′ into the following *linear* vector differential equation.

$$\frac{d\mathbf{a}}{dt} = \mathbf{A}\mathbf{a} + \mathbf{B}\mathbf{b} \quad (13)$$

$\mathbf{A}$ is a constant $n \times n$ matrix whose elements are given by

$$a_{ij} = \left.\frac{\partial f_i}{\partial x_j}\right|_{\substack{\mathbf{x} = \mathbf{x}^* \\ \mathbf{u} = \mathbf{u}^*}} \qquad i, j = 1, 2, \ldots, n$$

$\mathbf{B}$ is a constant $n \times m$ matrix whose elements are given by

$$b_{ij} = \left.\frac{\partial f_i}{\partial u_j}\right|_{\substack{\mathbf{x} = \mathbf{x}^* \\ \mathbf{u} = \mathbf{u}^*}} \qquad \begin{matrix} i = 1, 2, \ldots, n \\ j = 1, 2, \ldots, m \end{matrix}$$

$\mathbf{a}$ and $\mathbf{b}$ are merely n-dimensional column vectors. Evidently, $\mathbf{a}$ represents the state of the system, $\mathbf{b}$ the control vector, and $\mathbf{A}$ specifies the dynamics of the process in the neighborhood of the assumed equilibrium state. Thus the problem has been transformed from a nonlinear to a linear set of equations. The solution of Equation 13 is given by

$$\mathbf{a}(t) = \Phi(t - t_0)\,\mathbf{a}(t_0) + \int_{t_0}^{t} \Phi(t - \tau)\,\mathbf{B}\mathbf{b}(\tau)\,d\tau \quad (14)$$

where $\Phi(t)$ is the transition matrix given by the exponential function

$$\Phi(t) = e^{t\mathbf{A}} = \sum_{k=0}^{\infty} \frac{\mathbf{A}^k t^k}{k!} \quad (15)$$

The first term on the right of equation 14 is the **homogeneous** solution of 13 and the second term is the **particular** solution.

When the control vector $\mathbf{b}$ is taken as constant between sampling instants

. . . For any control system to achieve a desired operation it is necessary to include, in some manner, a means of judging the performance of the process.

then Equation 14 may be simplified to

$$\mathbf{a}(t_0 + T) = \Phi(T)\mathbf{a}(t_0) + \left[\int_{t_0}^{t_0+T} \Phi(T-\tau)\mathbf{B}d\tau\right]\mathbf{b}(t_0) \qquad (16)$$

with the matrix in the large brackets being a constant. This equation may be thought of as the *basic difference equation* for the linearized process.

Strictly speaking **A** should be written as $\mathbf{A}(t; \mathbf{x}^s)$ since this matrix depends both on the equilibrium point chosen as well as on time. The dynamics of the process may change independently with time through changes in heat transfer coefficients, catalyst fouling, etc., and $\mathbf{x}^s$ may be altered by management decisions.

Performance index

For any control system to achieve a desired operation it is necessary to include, in some manner, a means of judging the performance of the process. In other words, it is necessary to state the type of performance desired for the process. The error or deviation from this desired performance must then be minimized so that the control system attains the required performance. Some obvious performance criteria are: to maximize the yield or throughput of the process, or to minimize the energy and material costs.

Thus, one starts by prescribing a set of desired values of the state variables, $x^d_1, x^d_2, \ldots, x^d_n$ or $\mathbf{x}^d$, based upon economic and management decisions, and then rapidly tries to bring the actual concentrations of the process, $x_1, x_2, \ldots, x_n$ or $\mathbf{x}$, as close as possible to the desired states. Since, because of inertia, it is impossible to bring $\mathbf{x}$ to $\mathbf{x}^d$ instantaneously, one must assign some penalty to the deviation of $\mathbf{x}$ from $\mathbf{x}^d$. This is usually called an *error criterion*. Wiener first suggested that control systems should be designed in such a way as to minimize the integrated squared error.

$$\int_0^\infty e^2(t)dt = \int_0^\infty [x_1^d - x_1(t)]^2 dt \qquad (17)$$

The utility of this index lies in the fact that minimizing the integral (or differentiating the integral) leads to a linear function of the error. It is often convenient, however, to define a more general measure of the error at any time t by means of the quadratic form

$$\beta^2(\mathbf{x}^d - \mathbf{x}) = (\mathbf{x}^d - \mathbf{x})'\mathbf{Q}(\mathbf{x}^d - \mathbf{x}) \qquad (18)$$

where the prime indicates the transpose of the vector and **Q** is any positive definite or semidefinite matrix. β is defined by means of this equation. Using Equation 18 a *performance index* can be defined by means of either

$$P(\mathbf{x}(t_0), \mathbf{x}^d) = \int_{t_0}^\infty \beta^2(\mathbf{x}^d - \mathbf{x})dt \qquad (19)$$

$$P(\mathbf{x}(t_0), \mathbf{x}^d) = \int_{t_0}^\infty \beta^2(\mathbf{x}^d - \mathbf{x}(t))e^{\alpha(t-t_0)}dt \qquad (20)$$

where α is a real positive constant. Note that the performance index is a function of the initial and desired states.

The dynamics of the process are included in this index since the value of $\mathbf{x}(t)$ is included. In Equation 20 the weighting function $e^{\alpha(t-t_0)}$ has been introduced so that the *present* errors are weighted less heavily than the *future* error. This takes into account the inevitable inertia of the process. Dynamic optimization of the process can now be stated as requiring that the control variables $u_1(t)$, $u_2(t)$, . . ., $u_m(t)$ or $\mathbf{u}(t)$ be varied in such a manner in the interval $t_0 \leq t < \infty$ that the performance index, Equation 20, is minimized.

While this requirement can be simply stated in words, the computational problem of actually carrying out the stated steps is very great due to the fact that one must find the particular optimal control vector function $\mathbf{u}^o(t)$ from among the set of all such functions which minimizes 20.

The following procedure considerably simplifies the problem: Since the control system is to be operated on a sampled basis, assume that the control variables are held constant between sampling times. As a result, it is only necessary to minimize equation 20 with respect to the sequence of discrete control vectors,

$$\mathbf{u}(t_0), \mathbf{u}(t_0 + T), \mathbf{u}(t_0 + 2T), \cdots \qquad (21)$$

Further, the integral in Equation 20 can be approximated by an infinite sum

$$P(\mathbf{x}(t_0), \mathbf{x}^d) = \sum_{k=1}^\infty \beta^2[\mathbf{x}^d - \mathbf{x}(t_0 + kT)]e^{\alpha kT} \qquad (22)$$

The problem now becomes one of finding a control sequence of 21 such that the sum given by 22 is minimized. This can be accomplished by applying the Principle of Optimality due to Bellman (*1*).

> **Principle of Optimality:** An optimal sequence 21 of control variables has the property that, whatever the initial state of the process $\mathbf{x}(t_0)$ and the initial choice $\mathbf{u}^o(t_0)$ of the control vector, the remaining terms of the sequence $\mathbf{u}^o(t_0 + T)$, $\mathbf{u}^o(t_0 + 2T)$, . . . must constitute an optimal sequence with regard to the

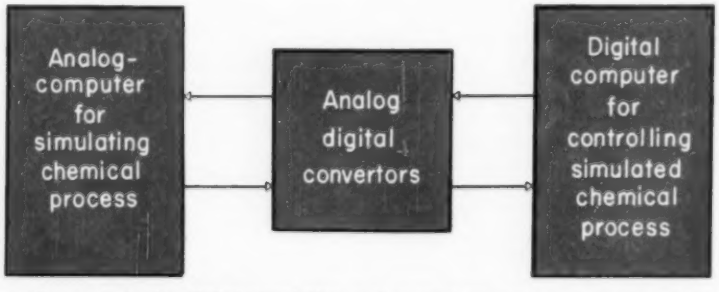

Analog-computer for simulating chemical process
Analog digital convertors
Digital computer for controlling simulated chemical process

Figure 2. Analog-digital simulation and control by means of analog-digital convertors operating in both directions.

state $\mathbf{x}(t_o + T)$ resulting from the choice of $\mathbf{u}^o(t_o)$.

Methods based on the Principle of Optimality are often referred to as *dynamic programming*. Without presenting the detailed implementation of this principle, the following statements can be made:

a. The minimization requires the solution of N one-step decision problems instead of a single N-step decision problem.

b. The sequence of one-step decision processes can be computed iteratively using simple recurrence relations if the dynamics of the process are linear.

c. In the limit, the iteration process always converges to yield the optimum sequence of control vectors for the process.

d. In the linear case, the states of the dynamically optimized system tend asymptotically to the same equilibrium state $\mathbf{x}^*$ which is obtained under static optimization.

e. The control system designed by this scheme is always stable; in fact, the transient response is faster than $e^{-\alpha t}$ where α is defined in Equation 20.

It is important to note the requirement that the dynamics of the process be linear. For this reason the control system obtained by the above procedure will be optimal only for the linearized version of the nonlinear dynamic equations. In the nonlinear case, the theory has not progressed far enough to permit significant practical applications.

First-order implementation

To implement the concepts discussed, in which a dynamic system is optimized in terms of the performance index by dynamic programming, the computational arrangement of Figure 2 has been assembled. This may be thought of as a Stage I implementation since it is used only to check out the behavior of ideal systems under closed-loop digital control.

An analog computer is shown in Figure 2 as directly connected to a large high speed digital computer through an analog-digital converter. The analog computer has 20 integrators, 20 summing amplifiers, 5 servos, and a random input generator, plus the normal output devices. The analog-digital converter employs a number of information channels to convert analog outputs into digital form and digital computer outputs into analog form. 20 analog-to-digital and 10 digital-to-analog channels are provided with all-solid-state circuitry. More than 400 conversions/sec. may be made on any channel with a conversion accuracy of $\pm 0.05\%$, equivalent to, *sign* plus 10 *bits* of binary data. Information transfer through the converters is determined by means of the digital computer program.

This computational setup allows the *real time* simulation of a chemical process on the analog computer, and the direct closed-loop control by means of the coupled digital computer. Questions of stability of the numerical computations, as well as of nonlinear effects, are currently being studied. As an example, an exothermic chemical reaction in a stirred reactor has been simulated on the analog, and controlled on a real time basis by the digital computer. In this case there were five state variables in the system and three control variables. The preliminary results were very encouraging. Detailed results of these computations, plus a variety of others will be described in forthcoming publications.

The second-order implementation of the present theoretical concepts would be to connect the converter system, plus the digital computer, to a real chemical process. It is not unrealistic to assume that such an arrangement can be accomplished in the near future.

Possible future system

Based upon the results obtained in the Stage I investigation, briefly outlined above, plus a number of other considerations, it is possible to outline some of the requirements for a complete digital computer control system as well as to speculate on its functions. The control computer is visualized as containing four main portions:

a. A program which uses the performance index for the process, the most up-to-date model for the system dynamics, and the last-measured values of the state variables to compute the necessary control variables. This portion of the digital computer would also, by means of suitable control signals, actually adjust the necessary control valves, etc. It may be thought of as replacing the conventional single-loop controllers.

b. Since an up-to-date knowledge of the dynamics of the process is necessary for the efficient operation of the over-all control, a second program in the computer will be used to monitor and update the dynamics. Based upon actual measurements, the coefficients in the dynamic model are revaluated periodically so that the latest and most accurate model is always available for program (a).

c. To update the dynamics by program (b), it may be required to perturb the process in some intelligent and periodic fashion. This is necessary, since if the system is operating at or near an equilibrium state, measurement of the state variables may not provide sufficiently clear information regarding the dynamics of the process. Thus program (c) would periodically perturb the process with special calibrating signals which are in the neighborhood of the process noise level, but which generate fluctuations in the output which can be interpreted by sophisticated data reduction techniques.

d. As required, the unmeasurable state variables may be generated from the measured ones, using the dynamic model of the process and standard statistical prediction techniques (*2*).

All four programs must be monitored by some multiplexing device in the digital computer which specifies the program to be carried out. The generation of the digital computer programs specified is not trivial, but present results indicate that it is possible, even today, to construct a considerable portion of this system.

As outlined, the control computer may be called an adaptive or self-optimizing system. The computer adapts itself to the process by updating the dynamics as determined by the latest operating conditions and then seeking the optimum level of process performance. In a sense this may be thought of as a form of feedback. Thus the addition of programs (b) and (d), above, would constitute a major advancement in the automatic control of chemical processes as compared to present-day methods.

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2-Computer control of Processes

Is it worth the cost?

You may be able to reap the benefits of computer control without using a computer.

C. R. Hall

Chemical companies, like other industrial concerns, are in business primarily to earn money within accepted ethical, sociological, and legal restraints. Thus the acceptance and application of any new equipment or system depends upon how it will help earn money—and how much money. This article, therefore, is concerned primarily with the problem of applying computers in the control of processes to earn more money for chemical companies.

Since there are many types, sizes, and degrees of complexity of computers, and since the phrase "computer-controlled process" may mean something different to each individual, depending upon his knowledge and background, a definition for the purposes of this paper is in order. By computer-controlled process is meant —a digital, internally-programmed, general-purpose type of computer:

1. Continually and automatically receiving operating data from a process.
2. Making certain predetermined computations using that data.
3. Directly manipulating the controllable variables of the process as a result of these computations.

A major reason for this definition is that general purpose digital computers for process control are available to industry today. They are expensive. There are many claims as to their value in process control, and there is little actual (published) experience in their use. One of the greatest problems connected with the installation of computer control on a process is the large cost involved in a single application. There are some fairly good figures available to date from the equipment manufacturers, plus the experience of some users and would-be users.

For a typical cost example, in order to relate it to equipment now available for use, a medium-sized process, or part of a larger complex, is cited. This would have in the range of 100 to 200 input values (temperatures, pressures, flows, etc.) and perhaps 10 to 25 output control or alarm functions.

First, there is the cost of the computer itself, ranging from $100,000 to $150,000, depending upon its speed, special "built-in" accessories needed for the job, and the vendor.

Second, there is the cost of accessories that are not built in, but are equally essential to the application. These include certain input-output facilities. Much depends upon both the existing process facilities and the computer being considered. It may include pneumatic to electric transducers, special signal amplifiers, stepping switches, and whatever methods are chosen for converting the electric pulses of digital output into mechanical action of a valve or controller set-point. Fifty thousand dollars could be a good average value for the size process mentioned above.

Finally there is the cost of engineering the job. This figure includes all of the problem analysis as well as the equipment engineering and design. That is to say, the mathematical analysis, systems engineering, special

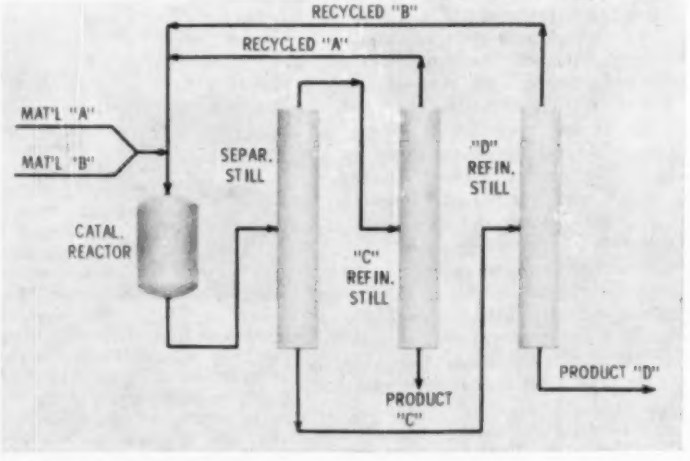


Figure 1. A catalytic reaction system.

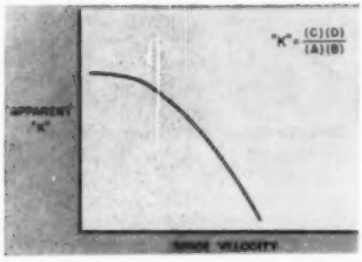


Figure 2. Reaction equilibrium vs. space velocity.

tests, computation and simulation, and programming are included at this point. A rather wide range of $50,000 to $150,000 is allowed here since so much depends upon how much is already known of the the process, the experience of the people conducting the analysis, and the accounting procedures of the individual company.

Even if one maintains some degree of optimism, the cost will be, at least, in the quarter-million-dollar range. To consider the expenditure of such a sum of money, it is necessary to examine the possible benefits of the proposed installation to decide whether the expenditure is justified. Once this is done, the rest is straightforward. The proposal merely competes with other projects for the available investment money. If the payout is good it will probably be authorized. If others are better, it may be delayed. One suggestion frequently advanced is a trial installation on a research basis to find out what benefits result. Fortunately, there are many ideas competing for the research dollars, and again potential benefit becomes a problem.

Two typical cases are discussed below which illustrate some of the problems which arise in attempting to develop the dollar return on computer process control.

Catalytic reaction system

Figure 1 shows a sketch of the process. Raw materials *A* and *B* join with recycled streams and pass through the catalyst bed in the liquid phase. The reactor effluent goes first to a separation still where the tops, consisting of product *C* and unreacted *A*, are separated from product *D*, and unreacted *B*. Both the tops and bottoms from this still go to separate refining stills for further separation and recycle. The performance of the separation and refining stills is the key to product quality. This performance also has a strong influence upon the capacity of the reactor. If much of the products *C* or *D* are recycled to the reactor, its performance is seriously affected, as will be shown later.

The problem here is that an increase in capacity of the system by 25% is to be required soon. An estimate had been made indicating that over $1,000,000 would be required for larger facilities to attain the required capacity, primarily for larger stills. Here was a possibility of investigating improved control through the use of a computer as a means for reducing the investment required for the expansion. All that was needed was to find a way, and to be sure that more than the cost of the computer installation would be saved. After examining existing instrument charts and operating log sheets, improved control was judged certainly possible. Thus, work was undertaken to develop the means of improvement and the quantitative value of so doing.

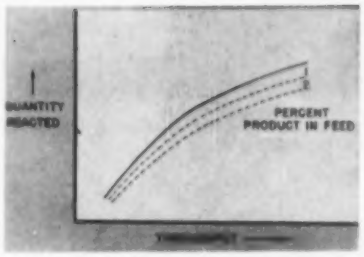


Figure 3. Productivity relationships are non-linear.

A key bit of information pointing toward potential gains from advanced control concepts is shown in Figure 2. This information, developed from original research on the process and confirmed in plant operation, shows the lumped effect upon reaction rate

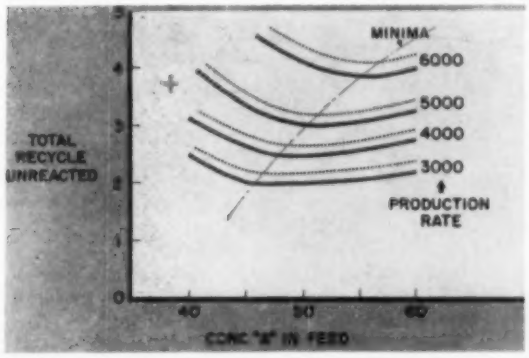


Figure 4. Reactor feed composition and recycle rate.

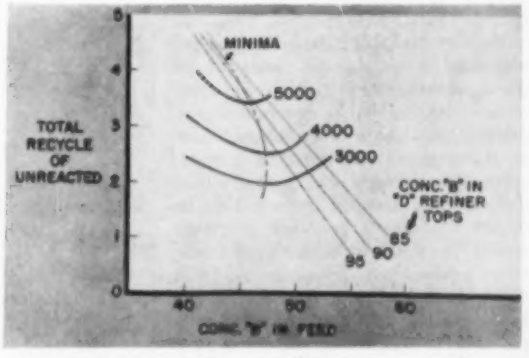


Figure 5. System effect on recycle rate.

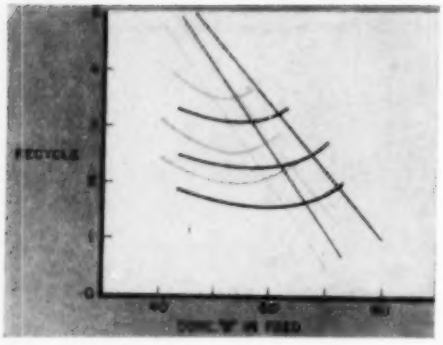


Figure 6. Before and after. A larger reactor requires more plates.

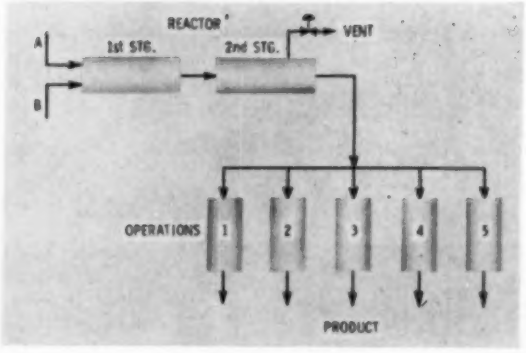


Figure 7. A sample process requiring quality control.

of throughput rate, amount of catalyst, and concentrations. The latter are calculated as the equilibrium constant and the curve shows how this quotient varies with space velocity. The relationship is nonlinear, hence one would expect nonlinear relationships of productivity with feed rates and, due to the form of the equilibrium equation, expect added nonlinear effects from concentration variations of the feed.

The results of several numerical calculations are plotted in Figure 3. The solid line is the case where the feed to the reactor is pure *A* and *B*. The quantity of *A* reacted is plotted against throughput rate. It can be seen that, while the quantity of *A* reacted continues to increase as throughput rate is increased, the incremental gain becomes less and less. Hence from a system point of view, the increasing dilution of the product in the reactor effluent means an increasing load on the subsequent stills out of proportion to the increased production rate. The dotted curves show the effect of small amounts of product (*C* or *D*—or both) in the feed upon the reaction of *A*. The effect of product in the feed upon throughput required for a given conversion of *A* is apparent.

Another variable influencing the reaction of *A* with *B*, as indicated by the equilibrium equation, is the ratio of reactants. For the maximum production of *C* and *D* at any value of *K*, the denominator must be a maximum. Considering the reactor alone, the conclusion could immediately be drawn that most profitable operation would be under conditions of maximum productivity. These would be at an equimolal ratio of *A* and *B* in the feed, while containing a minimum of products *C* or *D*.

At this point it must be remembered that the stills in the process are really an integral part of the system. Their capacity and performance, due to the recycle of unreacted materials, should in turn affect the reactor. Furthermore, the nonlinear relationships described earlier, may provide some interesting aspects. Thus, the quantity of recycled feeds can provide a measure of system performance. Figure 4 shows the result of this analysis when total recycle is plotted against concentration of *B* in the feed for different production rates of *C* and *D*. It may be noted that the concentration of *B* for minimum recycle of unreacted feeds is not constant for all production rates. The cross shows the normal operating point of the plant. The dotted lines show the increased level of recycle for the same productions indicated by the solid lines, when there is 1% of product *C* or *D* in the feed to the reactor. The optimums shown would provide most economical operation from a system point of view. This basically amounts to steam savings—and doesn't amount to much.

This is fine for normal operation. But what about the time when the system is being run at, or exceeding, the design capacity of the refining stills? This capacity aspect was the basic reason for the investigation. From a further examination of the system (including a breakdown of the components making up the total recycle) for capacity limitations, the *D* refining still was found to be the first capacity bottleneck. The effect on the system of changing its operation from the design basis was investigated.

Thus, one means of accommodating an increased load on the *D* refining column without affecting the quality of *D* out the bottom is to cut back on the reflux ratio. This, of course, incurs the penalty of a greater concentration of *D* in the overhead. This in turn would have a serious effect upon

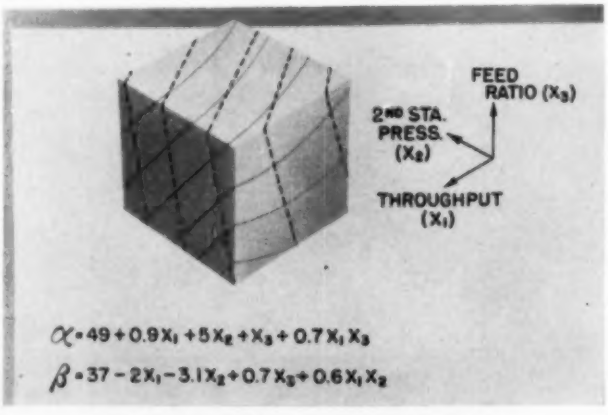


Figure 8. Quality relationships vs. controllable variables.

the reaction when that overhead material joined the feed to the reactor. The situation would compound itself as there would be more and more unreacted B for recycle, an unstable situation. Changing the mol ratio of *B* to *A* in the feed can compensate for this, in part. Admittedly, changing the mol ratio in either direction decreases the conversion (increases the recycle of unreacted material), but the individual effect upon the recycle of *B* by decreasing the *B*-to-*A* ratio is much greater than the effect resulting from reduced conversion.

Figure 5 shows the net result by superposing the performance of the *D* refining still upon the total recycle figure. Here the diagonal lines show the performance of *D* refiner column in balance with the reactor and overall rates. They are labeled as concentration of *B* in the tops. They could just as well have been labeled as reflux ratios. Note how the total recycle curves have changed and that the B-to-A ratio in the feed for minimum recycle, as restrained by the next-limiting equipment piece (*D* refiner), varies in a different fashion as production rates are changed. This changing optimum is rather abrupt, such that at high production rates close surveillance is required to avoid exceeding the optimum value of *B*. One cannot hold the concentration of *B* well below the optimum either, for the capacity of *C* refiner provides a similar restraint, though this is not shown.

Since all of these curves and families of curves can be expressed as mathematical equations, this appears to be a job that should be amenable to computer control. It appears complex enough to require either computer control or modified process equipment—and computer control would cost considerably less than the $1,000,000-plus, which was previously estimated.

A process engineer following the analysis closely raised an interesting question. Recognizing that the crux of the problem lay in the variation of productivity with throughput rate, he wondered what would happen if the reactor were made twice as big. This could be done for only $10,000 to $20,000 since it was an inexpensive type. He also mentioned that the plant was planning to increase the number of plates in the *D* refiner column by a significant amount on a maintenance basis—replacing some which were completely corroded.

Figure 6 shows the before and after of these alterations. Enlarging the reactor, such that the apparent equilibrium constant remains at a high value for all expected rates, flattens the recycle curves considerably, and reduces the recycle at all production rates. This reduces the sensitivity of the feed composition. The additional plates in the *D* refining column move the diagonal lines, representing its performance, to the right. Thus, one process which might have had computer control applied effectively for increased capacity, will achieve that capacity for about a tenth the cost of computer control.

Figure 7 is a sketch of a process whose quality is to be controlled. Materials *A* and *B* are fed into the first stage of the reactor where temperature and pressure are held constant. The effluent passes to a second stage where the pressure is reduced and the reaction driven toward completion. At the outlet of this second stage, quality is of prime importance, for the succeeding operations are based upon consistent, closely controlled quality considerations. The operations, shown as the blocks numbered 1 through 5, are unusual in that each may operate successfully at only three discrete throughput rates to make a saleable finished product.

The basic problem here is to accommodate these throughput changes (which are made necessary by the changing market demands) without affecting the quality charac-

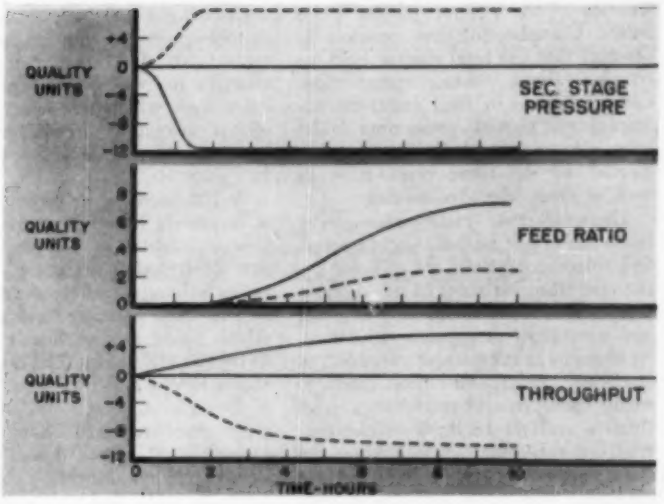


Figure 9. Transient response to controlled variables.

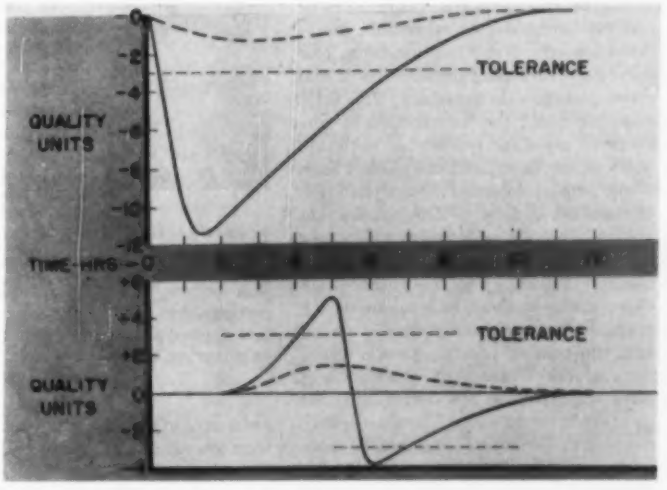


Figure 10. Compensating transients.

teristics at the reactor second stage outlet. Complicating the problem is the fact that the total reactor hold-up equals about 4-hr. production. Changes made in feed ratio, for example, will require some time to be fully effective at the reactor outlet. There will be some dead time as well as some effects of mixing.

There are two quality characteristics which must be held within specified tolerances. Both are affected by the operating variables of the process. They are affected to differing degrees, and sometimes in opposite directions, by changes in the process variables. A statistical analysis had been made to relate these two characteristics (call them α and β) to three of the controllable variables, while holding the other process variables substantially constant. The three controllable variables considered were *A*-to-*B* ratio in the feed, throughput rate, and second stage pressure.

Figure 8 shows the result of this analysis and the two regression equations describing the relationships. The cube represents the dimensions of the three controllable variables. The solid lines represent the intersection of surfaces of constant quality α, with the faces of the cube, and the dotted lines show similar intersections of surfaces of constant quality β. This means that within the three-dimensional space there are surfaces representing equal quality values. The coordinates of these surfaces show the values of the controllable variables required to attain the quality levels represented by the surfaces. The equations are simple, no squared terms and only one cross-product term in each. The cross-product term, however, provides a nonlinearity that required the above use of the word "surface" instead of "plane."

From other experimental work on the amount of mixing to be expected in the fluid passing through the two reactor stages, the dynamics of changes in the three variables upon α and β could be approximated, Figure 9. In each graph the change in the variable is assumed to be made stepwise, or instantaneously, at zero time. The curves represent the quality values at the outlet of the second reactor stage and how they change with time. Here the solid line is quality α, and the dotted line represents quality β, as before. An important point is that if the starting point in the three-dimensional space of Figure 8 had been different from that chosen for these examples, the amplitudes of the quality changes would also be different.

The quality changes for given variable changes can be calculated both as to amount and time of their occurrence. So also, may compensating changes in two of the variables be calculated, which will cancel out the effects on quality of required changes in the third variable. This is illustrated in Figure 10.

A 10% increase in throughput rate is required. This will cause a variation in qualities α and β, similar to that described in Figure 9. Compensating changes in feed ratio and second stage pressure were calculated which bring the quality levels back to their initial values. The top diagram shows how α and β change with time if throughput, feed ratio, and second stage pressure were changed simultaneously at zero time. While β doesn't change much, α changes almost 12 units and gradually returns within tolerance in about 6½ hr. The bottom diagram shows what the fluctuations would be with a little more thought given to the way the changes are made. In this case, the feed ratio is changed at zero time, then the throughput and second stage pressure are changed at plus 5 hr. Here the time that quality is out of specification is only about 3 hr. One can readily visualize increasingly complex programs to further minimize these fluctuations.

C. R. Hall is on special assignment at Du Pont to examine potential applications of computer control to Du Pont's processes. He joined the company engineering department in 1947, and has worked in a variety of positions, including task force process development, technical process improvement, and research. Hall also supervised the engineering computation group in charge of Univac and applied mathematics, statistics and engineering analyses.

The nonlinearity of the relationships rules out a single program for all changes. The quality fluctuations for the same throughput change and differing initial conditions are quite different from those shown.

Here it was possible to visualize a single computer controlling the changes for several reactor systems, holding quality within very narrow limits, despite almost any throughput change. With a little more analysis the reactor environmental conditions might also be included in the control to further reduce fluctuations. This could be a big step toward the push-button plant, while saving around $200,000/yr. of scrap material.

One of the process engineers, noting that precise timing of compensating action was required largely because of the step change in throughput, got the idea of giving the process some extra time in which to recover by deliberately making some scrap between the reactor second stage and the subsequent operation. He found he could change the throughput of the operation blocks by the required increments, yet change the reactor throughput gradually. In so doing he literally bought the time to make changes in the other variables such that precision in timing and amount of compensation were not critical. The amount of scrap made—still within specifications of α and β—was considerably less than that which had been made previously. This reduced the potential benefits from computer control to the point where it was no longer justified.

These have been specific examples of process examination, seeking justified application of computers for control. They were presented to illustrate some of the problems involved in such work. On the brighter side, however, investigations other than those described have continued to show real promise. One point of major importance has been learned in the conduct of this work. The type of analysis imposed in seeking advantages of complex control of a process is usually highly profitable, whether or not a computer is ultimately required. In trying to discover all the interrelationships of variables influencing the process, a true definition of the system results from the analysis. Arbitrary system definition, such as "this reactor" or "that still," frequently can have little bearing on all the real factors that influence performance.

At some risk of being considered negative on the subject of computer control of processes, the following conclusions may be drawn from this work:

1. The application of a digital, internally-programmed, general-purpose computer for control of a process will cost from $200,000 up.
2. There will be many chemical processes where, after comprehensive system analysis, lower cost process changes or lower cost control changes (perhaps involving computational elements) may be made which will achieve the major share of the benefits that computer control would otherwise obtain. #

JOHN W. KELLETT AND ALBERT S. PERLEY

Economic design by computer

. . . the computer is quicker than the hand

FOR THE PAST THREE years, Esso Research and Engineering Company has been preparing general purpose computer programs for engineering calculations. Its experience has been mainly with programs for process engineering, equipment process design, and cost estimating on the IBM 650 and 704 computers. The results of this work are used in designing refinery units for various affiliated companies of Standard Oil Company (New Jersey).

This article discussing the experience, accomplishments, and future plans in this field is divided into three main sections, covering:

1. A historical summary of the preparation of programs for design and cost estimating.
2. The potentialities of computers in permitting the use of improved calculation methods which are not feasible by hand, and an example of a cost estimating program which uses such an improved method.
3. Present incentive and future potential for the use of computers in design and cost estimating, and resulting future plans. These plans involve methods which are even more dependent on the availability of computers than those described in section 2.

Growth of computer use

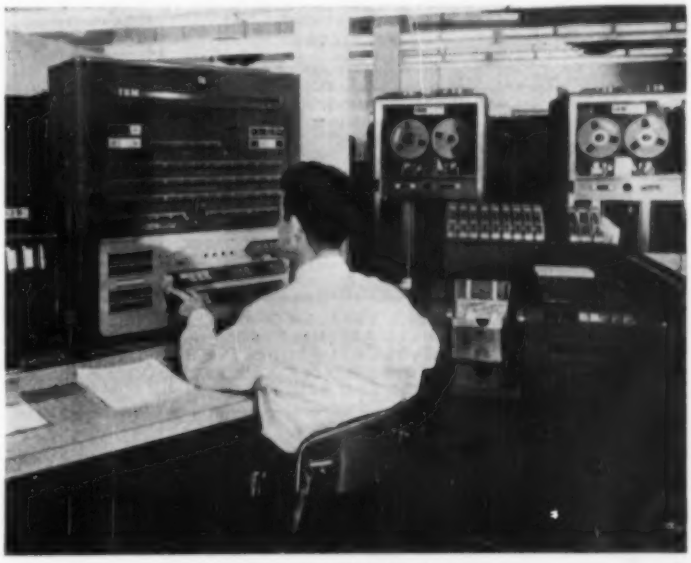
Esso began a concerted effort to apply computers to engineering calculations in 1955. At that time, programming began for a medium-size computer, the IBM 650. Programming was carried out on a number of important and widely used calculations for both design and cost estimating (*1*). Because of increasing computing needs, a large scientific computer, the IBM 704, was installed and began operations in December, 1957.

A number of general purpose engineering programs are now in use. Most of them are shown in Table 1. They include 650 programs, which are being run in translation on the 704, and programs specifically prepared for the 704. These programs have been accepted and are frequently used by the engineers. In fact, the engineers now depend heavily on some of the more important programs, and have requested that these programs be expanded to handle more varied cases and to do a larger portion of the total calculations.

Programmers work closely with program users

As in many other organizations, engineering programs are prepared by engineers rather than by computing experts. This means that engineers proficient in technical calculations must first learn the basics of programming. They then prepare new programs with the help of non-engineering personnel, and with advisory assistance from a nucleus of programming experts.

At first, computer programming of engineering calculations was done by assigning men on loan from project design and cost estimating sections to work under supervision of the group which operated the computer. This provided a convenient way to start, and substantial progress was made. However, it was only after a period



IBM 704 in use at Esso Research & Engineering.

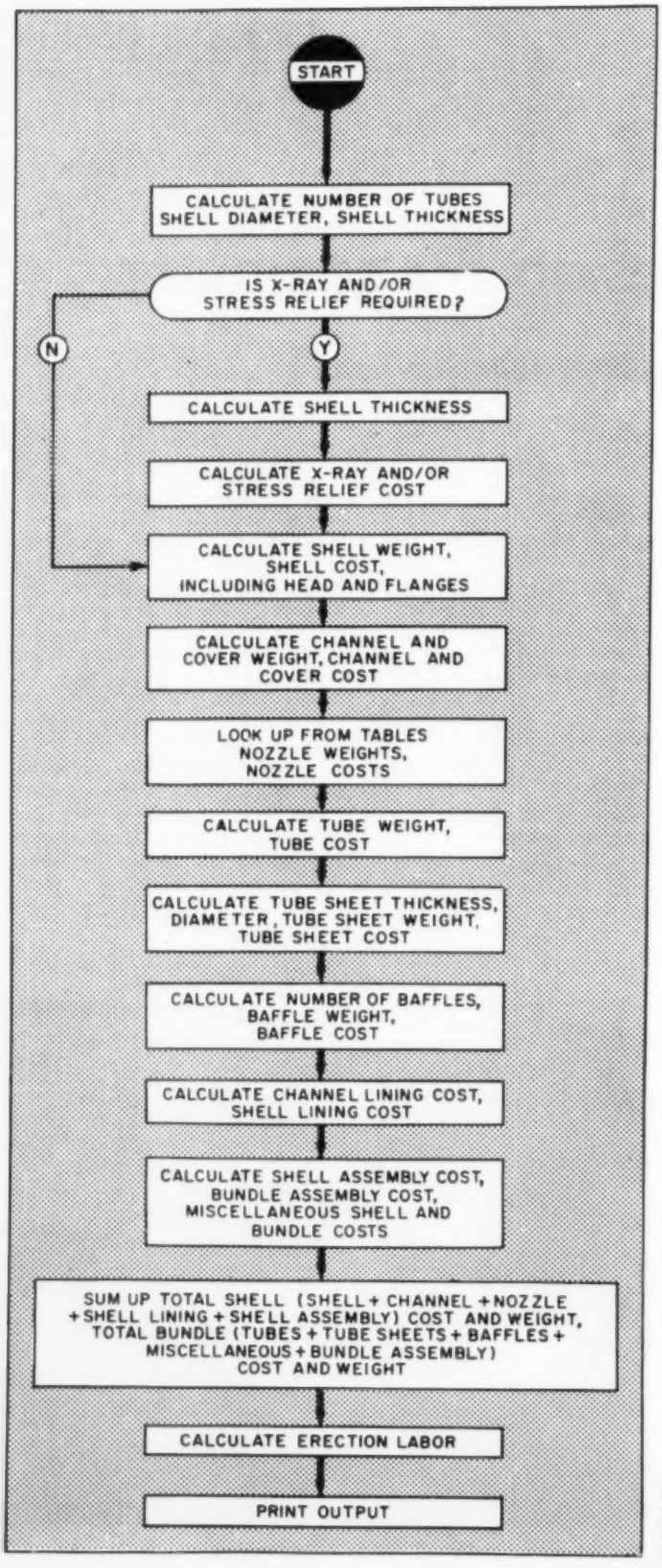

START
CALCULATE NUMBER OF TUBES SHELL DIAMETER, SHELL THICKNESS
IS X-RAY AND/OR STRESS RELIEF REQUIRED?
N
Y
CALCULATE SHELL THICKNESS
CALCULATE X-RAY AND/OR STRESS RELIEF COST
CALCULATE SHELL WEIGHT, SHELL COST, INCLUDING HEAD AND FLANGES
CALCULATE CHANNEL AND COVER WEIGHT, CHANNEL AND COVER COST
LOOK UP FROM TABLES NOZZLE WEIGHTS, NOZZLE COSTS
CALCULATE TUBE WEIGHT, TUBE COST
CALCULATE TUBE SHEET THICKNESS, DIAMETER, TUBE SHEET WEIGHT, TUBE SHEET COST
CALCULATE NUMBER OF BAFFLES, BAFFLE WEIGHT, BAFFLE COST
CALCULATE CHANNEL LINING COST, SHELL LINING COST
CALCULATE SHELL ASSEMBLY COST, BUNDLE ASSEMBLY COST, MISCELLANEOUS SHELL AND BUNDLE COSTS
SUM UP TOTAL SHELL (SHELL + CHANNEL + NOZZLE + SHELL LINING + SHELL ASSEMBLY) COST AND WEIGHT, TOTAL BUNDLE (TUBES + TUBE SHEETS + BAFFLES + MISCELLANEOUS + BUNDLE ASSEMBLY) COST AND WEIGHT
CALCULATE ERECTION LABOR
PRINT OUTPUT

Figure 1. Given the basic design information, the Heat Exchanger Cost Estimating Program designs the components in detail and calculates costs of each component.

of time that the deficiencies became apparent. The computing group was not in a position to supervise the engineering aspects of the programs; lack of continuing engineering responsibility led to a situation where the programs prepared were too limited in scope, and when completed, were not properly maintained and improved.

To alleviate this situation, programming is now being carried out by groups closely allied with, and under the same general supervision as, the groups which use their programs. That is, the group programming cost estimating calculations is part of the estimating forces, and the group programming design calculations is part of the design forces.

Table 1. Engineering programs now in use.

Process engineering
- Dew point, bubble point, and flash vaporization
- Properties of vaporizing hydrocarbon–steam system
- Minimum reflux
- Light ends tower process engineering
- Pipe still process engineering
- Absorber process engineering
- Thermal cracking furnace radiant coil calculations
- Multi-stage alkylation reactor process engineering

Equipment design
- Furnace pressure drop
- Heat exchangers
- Fractionating trays
- Drums
- Pipe sizing

Cost estimating
- Pressure vessels
- Heat exchangers
- Pumps
- Piping
- Concrete foundations

The design programs have become quite large and complex. And they in turn must be considered as building blocks for even larger programs. To develop and maintain the expertness required in such cases, the design programming group now has several engineers as permanent members, as opposed to engineers loaned for specific programming projects.

Computers permit improved methods

One of the most important considerations in programming is the improvement in calculation methods which is allowed, and in fact promoted, by the use of computers. In

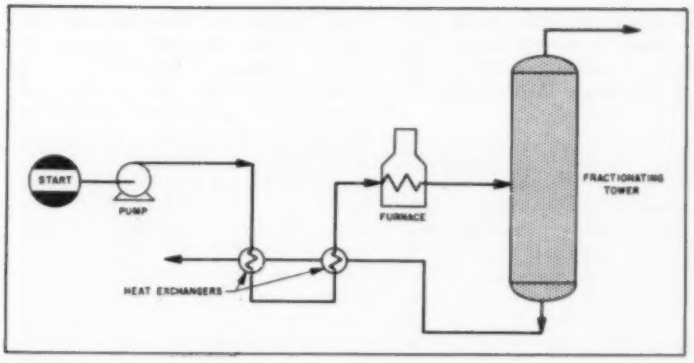


Figure 2. A simplified tower bottoms system whose design is to be worked out by the optimized computer program of Figure 3.

Esso the art of making engineering calculations followed a typical path. As the need arose, procedures were developed. Through usage, after successive improvements, these procedures became "established." Eventually, the established procedures were documented in the form of design and estimating manuals. Initial programming efforts were directed toward translating these existing "hand methods" into computer programs.

In programming a procedure from one of these manuals, it soon became apparent that there were "holes" which were ordinarily filled by the engineers' experience, judgment, or "by asking an expert." Also, the procedures were found to cover only the ranges of relatively frequent usage. Extrapolations were made by the engineer as the need arose, and without consistency.

Of course, these holes and extrapolations must be eliminated from a computer program, since the computer has no experience or judgment and cannot readily ask an expert. The programmer must have enough experience to plug the right holes properly, and to set up other holes so that judgment can be supplied by the program user. Polishing up the procedures for programming stimulates creative thought and always results in improvements.

New methods are often advisable

It is often wiser to discard established procedures in favor of more basic methods, which may not have been practical for hand calculations, but are quite suitable for a computer. A case in point is the Heat Exchanger Cost Estimating Program.

In the past, heat exchanger costs had been calculated from a family of curves giving cost as a function of heat exchanger area for various materials. Costs were adjusted for different pressures, tube lengths, bundle types, number of passes, etc. by means of percentages applied to a standard. These data were obtained by empirical correlation of actual prices paid. Results from using the method ranged from very accurate to rather poor.

To program this method accurately, it would be necessary to tie down percentage corrections through the full range in which the variables are likely to occur. To do this with any degree of accuracy would involve complicated correlations of a massive amount of price data, which are not available in any case.

The alternative is the method programmed, see Figure 1. Essentially, it mechanically designs the exchanger and prices the components to arrive at a total. The input data consist of heat transfer area, design pressure, tube size and type, etc. From the input data, the shell size, thickness, and other mechanical design characteristics are calculated. Unit prices are applied to the components and the costs are totalized into either shell or bundle cost. All significant data are printed out. The program will handle 3 types of exchangers, as well as 15 different materials of construction for each component.

This procedure would be very tedious by hand, but is a simple matter by computer. The method is completely flexible, giving answers of comparable accuracy over the full range of variables. Up-to-date exchanger prices are not needed to maintain a fair degree of accuracy, since the cost of components can be obtained largely from published price lists. Furthermore, this program can generate (with reasonable accuracy) the cost of a peculiar type heat exchanger from the cost of components, even though no actual bid prices are available on the heat exchanger itself.

Incentives and future plans

The use of computers in engineering design and cost estimating can save money in yielding designs which represent better, cheaper units, and in reducing the manpower required. Savings obtainable through better designs are an order of magnitude greater than manpower savings. Actually, like many other technological developments, the advent of computers may open up so many new possibilities that operation for maximum profit will require an increase in technical personnel.

Best designs involve optimization

Ideally, designs are optimized by balancing investment, operating costs,

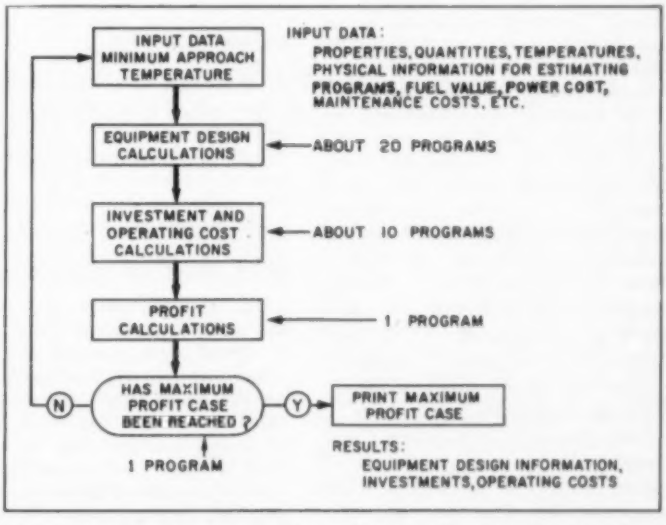

INPUT DATA MINIMUM APPROACH TEMPERATURE
INPUT DATA: PROPERTIES, QUANTITIES, TEMPERATURES, PHYSICAL INFORMATION FOR ESTIMATING PROGRAMS, FUEL VALUE, POWER COST, MAINTENANCE COSTS, ETC.
EQUIPMENT DESIGN CALCULATIONS
ABOUT 20 PROGRAMS
INVESTMENT AND OPERATING COST CALCULATIONS
ABOUT 10 PROGRAMS
PROFIT CALCULATIONS
1 PROGRAM
HAS MAXIMUM PROFIT CASE BEEN REACHED ?
N
Y
PRINT MAXIMUM PROFIT CASE
1 PROGRAM
RESULTS: EQUIPMENT DESIGN INFORMATION, INVESTMENTS, OPERATING COSTS

Figure 3. Program for optimized design of tower bottoms system.

and product values. Traditionally, optimization of designs has been handled by the application of experience and by using case studies. Experience alone can be deceptive and, at best, will give only a rough idea of the optimum. Hand calculation of case studies is widely done, and yields substantial design improvements with resultant savings.

In short-range analysis, the use of computers for design and estimating makes more case studies practical. It is a relatively easy task to run off many cases where the appropriate program is available.

Computer optimization—the ultimate

The next logical step is to integrate the design, cost estimating, and economic return calculations into an optimization routine on the computer. This is illustrated in Figure 2. The flow plan shows a tower feed system consisting of a feed pump, preheat/bottoms heat exchangers, furnace, and associated piping.

The problem is to determine the distribution of heat duty between the exchanger and furnace for maximum profit. Figure 3 is a logic diagram of a computer approach to this problem.

In general, the solution would take the following form. The inlet temperature for the tower would be calculated from the required fractionation. Assuming, as a first case, that the maximum amount of heat is transferred in the exchangers (minimum approach temperature between hot and cold fluid), design programs would take over to design the furnace, the heat exchanger train, the piping, and the pump capacity required. The next step would be an economic evaluation, including an estimate of the investment and operating costs for each of the components.

The estimated investment and operating costs would be stored for future reference. The program would then proceed to iterate in intervals of approach temperature (transferring more and more of the heat load from exchangers to furnace). At each of these intervals all of the equipment would be redesigned, the investments would be re-estimated, and the operating costs recalculated, followed by a calculation of the profit on the differential investments involved.

Once the optimum had been found, complete design information, including an estimate of investment, would be printed out. The optimum would then become the design basis. The design having been done on an integrated system, it would contain the multiplicity of small economies that would not be made in designing the components separately.

A problem such as this could be worked out by hand, of course. A close approach to the optimum could be obtained by designing and estimating several cases. However, this is expensive. In practice, this type of problem is seldom calculated rigorously. The optimum approach temperature is selected on the basis of past experience. This experience may or may not give valid results, depending on the particular case. It is very difficult for past experience to properly indicate such factors as differing relative investment costs (heat exchanger vs. furnace) and fuel values at many different locations.

Essentially, all crude oil pipe stills have a preheat system roughly similar

KELLETT

PERLEY

J. W. Kellett and A. S. Perley are long time members of the Esso Research and Engineering Lab. They have both covered the field of computers in economic design extensively in their work with the New Jersey firm. Kellett at present heads a group in computer applications in the Design Engineering Division. Perley has spent his entire working career with Esso, joining the firm in 1947 shortly after graduation from Lehigh University, where he obtained a BS in Mechanical Engineering. He is a section head in the planning engineering division.

to that shown in Figure 2. The investment for a 100,000 bbl./day atmospheric pipe still is about $5,000,000 of which about half is due to the preheat bottoms system. The incentive for a reduction in investment of only a few percent is obvious.

Much effort for optimization

The example above is a considerable over simplification of the problem of optimizing a preheat system. In actual practice, the final temperatures are not really fixed, and one has to consider not only the pump, preheat exchanger, and furnace, but also the heat transfer and fractionation in various sections of the tower. To consider all the variables is a complex problem, probably insurmountable by hand calculations. The size and complexity of the computer program required is shown in Figure 3.

Before a system such as this can be optimized, satisfactory methods for designing and estimating the components must be developed and programmed. Furthermore, methods must be devised and programmed for estimating marginal operating costs and product values. But the biggest problem is to develop a procedure to handle and optimize all the variables efficiently. This is an area which is relatively untouched so far.

Future programming

Work is continuing in programming component calculations for the 704. These are intended for use as building blocks in programs for doing a large part of the design and cost estimating work. In design work, a general dew point, bubble point, and equilibrium flash vaporization program has recently been completed, in which the input data consist only of the hydrocarbon composition and conditions. The equilibrium flash program itself will in turn be part of the condenser and vaporizer section of a general heat exchanger program, which will design essentially any shell and tube heat exchanger. Another program recently finished does the complete heat and material balance calculations for a pipe still.

In the field of cost estimating, work is proceeding on programs for pumps, compressors, and electrical power facilities, and will be extended to furnaces and other parts of basic process units. Subsequently, integration of the design and cost estimating programs, such as those for heat exchangers and furnaces, is planned.

The ultimate goal in this work is, of course, completely integrated programs for design, cost estimating, and economics, set up to yield optimum designs. How closely this goal may be economically approached at any future date depends on when the methods required to optimize efficiently will be developed, and when sufficiently large, fast, and more easily programmed computers will become available. But it is clear that there is a tremendous incentive for trying to attain optimum designs, and that if they are feasible, they will be made on a computer. They certainly will never be done by hand.

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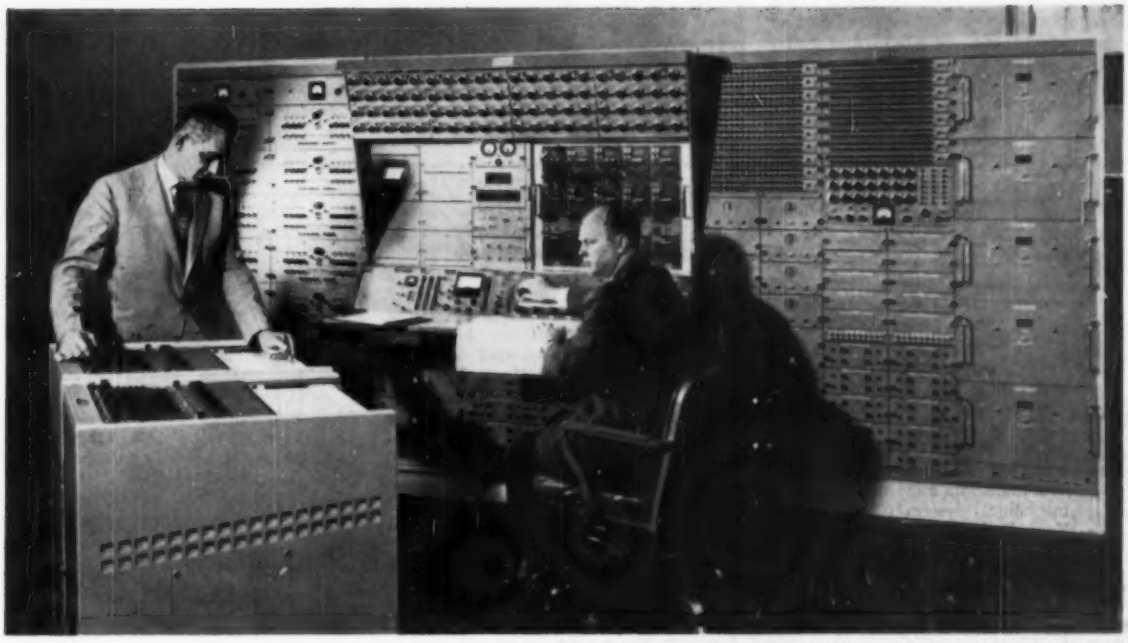


The 231R Analog Computing System of Electronic Associates in operation.

Analogs show the way

THEODORE J. WILLIAMS AND VERLIN A. LAUHER

Inherent quality of simulation makes analog computers a natural for telling a story. Use them as teaching aids in classrooms, laboratories, and in-plant instruction courses.

The analog computer has shown itself to be an excellent teaching aid in presenting the dynamic behavior of physical and chemical systems. The feelings of the authors regarding the use of analog computers as teaching aids are expressed in the motto of one of the manufacturer's of analog computing equipment. "The analog way is the model way." This article is a comprehensive listing of these computers with tabulations of the components required for typical classroom demonstration problems.

An analog computer, especially if it is of the electronic differential analyzer type, can be readily wired to simulate the behavior of a wide variety of physical systems. That is, it becomes an electronic *model* of each physical system and duplicates, through the variations of its internal voltages, the changes in the dependent variables of the process being simulated. It thus becomes one of the most effective classroom and laboratory demonstration aids possible, because it is then not necessary for the instructor to build physical representations of each of the examples being covered. Since the action of every dependent variable of the process can be recorded, an analog computer demonstration is often more vivid than the observation of the actual process itself, particularly if a chemical reaction or other non-visible phenomenon is being simulated.

Some example simulations

Table 1A lists 31 different classroom-sized demonstration problems

which have been described in available literature. They are divided into linear (no multiplication or division required to solve the problem) and nonlinear (multiplication and/or division required) type problems. This separation has been made because most small-scale analogs do not come equipped with multipliers or facilities for division. However, these devices can be readily procured (Table 6) and will fit nearly all of the small computers. Unfortunately, they are among the most expensive items of computer hardware and can easily cost as much as the rest of the computer, in some cases. The problems listed in Table 1A are intended to be only representative of possible types. Many more could be listed. Table 1B lists the number of each type of computer component necessary to carry out the simulation of each of the problems of Table 1A. These listings should be helpful when compared with the specifications of specific small-scale analog computers listed in Table 2.

The chemical engineering instructor should note particularly the low proportion of chemical engineering-type problems that can be carried out

continued on page 74

Table 1A. Some example problems suitable for small-scale analog computation.

A. Linear Systems—No function generation or multiplication required.

1 – Falling body subject to gravitational force, no air resistance (*11*)
2 – Falling body subject to gravitational force and subject to a resistive force proportional to velocity (*11*)
3 – Simulation of the action of a bouncing ball (*1, 10*)
4 – Vibrations in a mass-spring-damper mechanical system (*7, 10, 11*)
5 – Forced vibrations in a mass-spring-damper mechanical system (*11*)
6 – Vibrations in a mass-spring-damper system with elastic stops (*6*)
7 – Oscillations of a tuned torsional pendulum (*1, 10*)
8 – Modes of vibration of a cantilever beam subjected to tip displacement (*13*)
9 – Consecutive and reversible first-order chemical reactions (*14*)
10 – Loading on a bridge caused by a vehicle (*8*)
11 – Mixing of chemical solutions in a series of well-stirred tanks. Example shown is for two tanks (*11*)
12 – Simulation of an isothermal catalytic reactor with a first-order reaction and axial diffusion only. Steady state operation (*7*)
13 – Process dynamics of a shell and tube heat exchanger (*16*)
14 – Dynamics of a high speed adaptive control system (*10*)

B. Nonlinear Systems – Multiplication and/or function generation required.

15 – Falling body subject to a medium whose resistance is proportional to the square of the velocity (*11*)
16 – Trajectory of a bomb or artillery shell (*1, 10*)
17 – Trajectory of a long-range ballistic missile, including firing and ballistic phases of programmed flight (*10*)
18 – Vibrations in a mass-spring-damper system with a nonlinear spring constant and either elastic or inelastic stops (*15*)
19 – Composition in a well-stirred tank with different input and output compositions (*11*)
20 – Kinetics of a set of simultaneous and consecutive second-order reactions (*10*)
21 – Simulation of a tubular reactor with a first-order reaction. Temperature and composition profile of reactor calculated vs. length (*7*)
22 – Simulation of the intake, exhaust and cylinder system of a reciprocating gas compressor (*7, 10*)
23 – Dynamic characteristics of a distillation column. Example shown is for three plates (*7*)
24 – Determination of the shape of the liquid zone in the zone-refining of metals or the shape of unsupported liquid drops (*13*)
25 – Simulation of the pressure control in a pneumatic system (*7*)
26 – Automatic control of the temperature in a heat transfer process consisting of a well-mixed kettle and jacket (*10*)
27 – Automatic control of the output of a reaction process consisting of a well-stirred reactor and a second-order process (*10*)
28 – Automatic control of a shell and tube heat exchanger (*16*)
29 – Solution of Mathieu's equation, $\ddot{y} + (1\text{-}E \cos t)\ y = 0$ (*11*)
30 – Solution of Legendre's equation, $(1\text{-}t^2)\ddot{y} - 2t\,\dot{y} + n\,(n+1)y = 0$. Example shown is for $n = 4$. (*11*)
31 – Solution of van der Pol's equation, $\ddot{X} - E\,(\dot{X} - \frac{X^3}{3}) + X = 0$. Example shown is for large E (*11*)

Table 1B. Equipment required to solve example problems of Table 1A.

Problem No.	Amplifiers: Integrators	Amplifiers: Summers or Inverters	Multipliers: If Servo	Multipliers: If Electronic	Recorder: Strip Chart	Recorder: x-y	Function Generators	Potentiometers	Relays	Diodes	Function Switches
1	2	–	–	–	X	–	–	3	–	–	–
2	2	–	–	–	X	–	–	4	–	–	–
3	4	2	–	–	–	X	–	7	4	–	–
4	2-3	1-3	–	–	X	X	–	3-6	–	–	–
5	4	2	–	–	X	X	–	5	–	–	–
6	2	1	–	–	X	–	–	5	–	2	–
7	4	2-4	–	–	–	X	–	4	–	–	–
8	8	4	–	–	X	–	–	10	–	–	–
9	2	2	–	–	X	–	–	6	–	–	–
10	4	3	–	–	–	X	–	–	–	–	–
11	2	1	–	–	X	–	–	4	–	–	–
12	4	2	–	–	–	X	–	6	–	–	2
13	11	15	–	–	X	–	–	–	–	–	2
14	2	3	–	–	X	–	–	–	3	–	–
15	2	2	1	1	X	–	–	2-4	–	–	–
16	4	6	2	4	–	X	–	9	–	–	–
17	5	4	1	2	–	X	–	12	5	–	–
18	2	3	1	2	X	–	–	1	–	2	–
19	2	2	1	1	X	–	–	5	–	–	–
20	4	6	1	2	–	X	–	14	–	–	–
21	4	14	3	5	–	X	1	21	–	–	–
22	3	8	2	2	–	X	–	10	–	4	–
23	7	7	4	8	X	–	–	7-14	–	–	–
24	3	6	4	5	–	X	–	6	–	–	–
25	8	8	2	3	X	–	–	20	–	4	2
26	3	12	1	1	X	–	–	15	–	–	–
27	4	14	2	4	X	–	–	15	–	–	–
28	11	20	1	5	X	–	–	–	–	–	–
29	4	3	1	1	–	X	–	3	–	–	–
30	4	2	1	1	–	X	–	5	–	–	–
31	2	4	1	2	–	X	–	2	–	–	–

Table 2. Recommended standard computers as specified by various manufacturers.

Manufacturer's No. Designation	Total Amplifiers	Summer Integrators	Summers Only	Inverters	Servo-Multipliers	Function-Generation	Diode Function Generators: Electronic Multipliers	Diode Function Generators: Variable	Diode Function Generators: Fixed Function	Relays	Potentiometers	Removal Patch Panel	Repetitive Operation	Stabilized Amplifiers	Stabilized Power Supply	Diodes	Computing Resistors	Function Switches	Transistorized	Digital Volt Meter	Available in Kit Form	Expandable	Portable
1 *Computer Systems* MC-400	12	6	6	..	1	..	..	..	..	2	16	..	..	X	X	4	..	..	..	..	..	..	..
2 *Donner*							2	1															
A. Model 3000	10	10	..	..	..	..	A	A	..	..	10	X	X	..	X	2	..	..	..	..	..	X	X
B. Model 3100	30	15	15	..	..	..	..	..	..	2	35	X	X	X	X	10	..	2	..	..	..	X	..
C. Model 3100 Expanded Nonlinear	40	15	15	10	..	..	6	6	..	2	55	X	X	X	X	10	..	2	..	..	..	X	X
							2	1	..														
D. Model 3400	10	10	..	..	..	..	A	A	..	..	10	X	X	X	X	2	..	..	..	..	..	X	X
E. Model 3500	10	10	..	..	..	..	..	..	..	..	10	..	X	X	X	..	..	..	X	..	..	..	X
							2	1	..														
F. Model 3600 (To be announced)	10	10	..	..	..	..	A	A	..	..	10	X	X	X	X	2	..	..	X	..	..	X	X
3 *Heath*																							
A. Model EC-1	9	9	..	..	..	..	..	..	..	..	5	..	X	..	X	..	..	..	..	..	X	..	X
B. Model ES-400	15	15	..	..	..	..	..	A	..	..	30	..	X	..	X	..	..	..	..	..	X	..	X
4 *Philbrick* K5-U																							
A. Asst. 51	5	5	..	..	..	..	..	..	..	1	20	..	..	X	X	..	..	..	..	..	..	X	..
B. Asst. 52	10	10	..	..	..	..	..	..	..	1	40	..	..	X	X	..	..	..	..	..	..	X	..
C. Asst. 53	15	15	..	..	..	..	..	..	..	1	60	..	..	X	X	..	..	..	..	..	..	X	..
D. Asst. 54	20	20	..	..	..	..	..	..	..	2	80	..	..	X	X	..	..	..	..	..	..	X	..
E. Asst. 55	..	..	..	..	..	..	2	1	2	..	..	..	X	X	X	..	..	..	..	..	..	X	..
5 *PACE TR-10*																							
A. Basic	10	4	6	..	..	..	..	..	..	..	10	..	..	X	X	1	35	..	X	..	..	..	X
B. Linear Expanded	20	8	12	..	..	..	..	..	..	..	24	..	..	X	X	1	80	2	X	..	..	..	X
									4														
C. Nonlinear Expanded	20	8	12	..	..	..	2	..	X[2]	1	24	..	..	X	X	1	80	2	X	..	..	..	X
PACE 221R																							
A. Basic	20	8	12	..	..	..	..	..	..	..	20	X	A	X	X	..	..	4	..	X	..	X	..
B. Expanded	60	18	27	15	6	X	6	6	..	6	80	X	A	X	X	9	..	12	..	X	..	X	..
6 *REAC C 301*	12	6	6	..	..	..	..	..	..	4	18	X	..	X	X	..	48	1	..	..	..	..	X
REAC C 302	12	6	6	..	..	..	..	..	..	4	18	X	..	X	X	..	64	1	..	..	..	..	X
7 *S.E.A. Calculateur Analogique Repetitif* *S.E.A. Analog Computers*	12	8	4	..	..	..	..	..	..	..	28	..	X	..	X	..	..	..	X	..	..	..	X
A. Type OME L-2	12	12	..	..	A	A	A	A	A	A	30	X	..	..	X	..	..	..	..	..	..	X	..
B. Type OME P-2	24	24	..	..	A	A	A	A	A	A	80	X	..	X	X	..	..	..	..	..	..	X	..
8 *Shorts* General Purpose Analogue Computer	18	Var	Var	..	..	..	Var	Var	Var	..	72	..	X	X	X	..	X	..	..	..	..	X	..
9 *Solartron* Space "30"	30	20	10	..	4	X	..	..	..	4	60	X	X	X	X	4	X	..	..	X	..	X	..

Notes

1. Data presented has been derived from manufacturer's literature. Since specifications often change with time, the most recent literature should be reconsulted to verify the data on any particular computer before purchase.

2. The "X" mark in a column in the table is taken to mean a yes answer; dots indicate no or none; "A" in the column indicates the particular component is available; and "Var" means the number of the components is variable, subject to the requirements of the purchaser.

on a linear machine. The vast majority of chemical process dynamics problems are nonlinear, unless they entail only first-order reactions, and otherwise have only temperature- and flow-insensitive parameters. Such cases are rare for realistic situations.

Available small analogs

A listing of all the small-scale analog computers suitable for classroom or laboratory demonstration use is given in Table 2, according to trade name. Corresponding manufacturers are listed in Table 3. In the interests of portability and/or relatively low-cost, only the small computers have been listed in these tables. However, the manufacturers of large-scale equipment are listed in Table 4 for those interested. Prices of the computers listed range from about $200.00 for the Heath EC-1 in kit form, through approximately $4000 for nonlinear versions of the Donner Model 3400, to $8000 for the nonlinear component versions of the PACE TR-10, and to approximately $20,000 for the fully-expanded Donner Model 3100 and basic PACE 26-221R. There are several possibilities available in the $1000-5000 price range. Thus the choice is determined only by the instructor's budget vs. computing flexibility balance. As mentioned before, because of the large proportion of nonlinear problems in chemical systems, the chemical engineering instructor must usually purchase a more flexible and capable system than others.

continued on next page

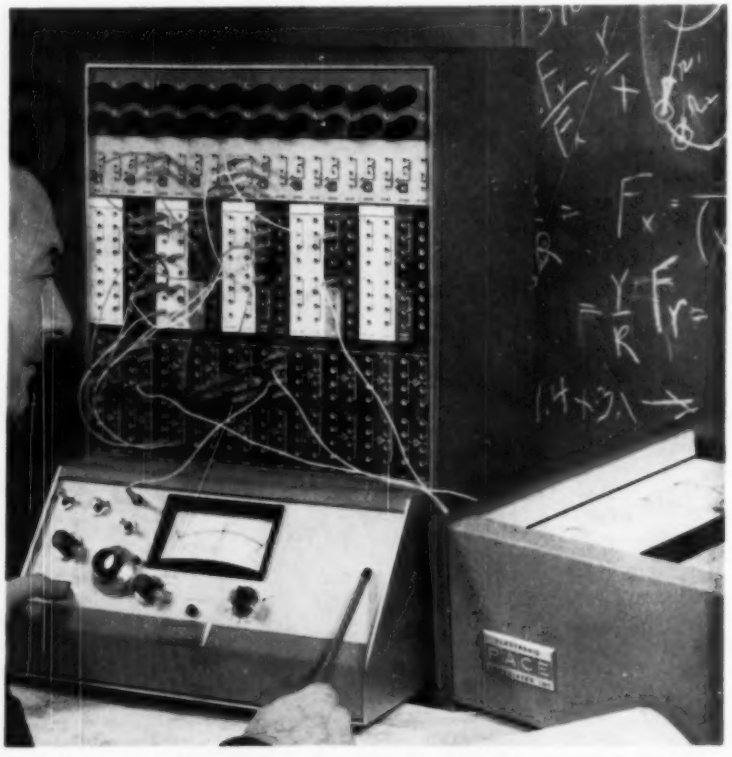
Table 3. Manufacturers and their tradenames.*

	Trade name	Manufacturer
1	Computer Systems	Computer Systems, Inc. 611 Broadway New York 12, N. Y.
2	Donner	Donner Scientific Company Concord, California
3	Heathkit	Heath Company Benton Harbor, Michigan
4	Philbrick K5-U	George A. Philbrick Researches, Inc. 285 Columbus Avenue Boston 16, Massachusetts
5	PACE	Electronic Associates, Inc. Long Branch, New Jersey
6	REAC C301, C302	Reeves Instrument Company East Gate Blvd., Roosevelt Field Garden City, L. I., N. Y.
7	S.E.A.	Societe d'Electronique et d'Automatisme 138 Boulevard de Verdun Courbevoie, Seine France
8	Shorts General Purpose Analogue Computer	Short Brothers and Harland Limited 208a East India House Regent Street, W. I. London, England
9	Solartron Space '30'	The Solartron Electronic Group Ltd. Thames Ditton Surry, England

* *Number corresponds to listing of Table 1.*

Table 4. Manufacturers of large-scale analog computing systems.

1. Berkeley Division, Beckman Instruments, Inc.
   2200 Wright Avenue
   Richmond 3, California
   (EASE 1100 Series Analog Computers)
2. Computer Systems, Inc.
   611 Broadway
   New York 12, N. Y.
   (MC-5800 Master Precision Analog Computer and MC-5900 Process Master Simulator and Computer)
3. Electronic Associates, Inc.
   Long Branch, N. J.
   (26-231R Electronic Analog Computers)
4. George A. Philbrick Researches, Inc.
   285 Columbus Avenue
   Boston 16, Massachusetts
   (GAP/R K3 and K5 Series Analog Computers)
5. Reeves Instrument Corporation
   East Gate Blvd., Roosevelt Field
   Garden City, L. I., New York
   (REAC 400 Series Analog Computers)



One of the latest developments in analog computers is the small, self-contained, transistorized model. This one is the PACE TR-10 of Electronic Associates.

Williams

Lauher

Theodore J. Williams is engineering supervisor in charge of the applications group at Monsanto's systems engineering section. Williams, who has degrees in both electrical and chemical engineering, taught at the Air Force Institute of Technology before joining Monsanto. V. A. Lauher is also in Monsanto's Research and Engineering Division, in the applications group. An electrical engineer, he joined the St. Louis firm in 1957 as a member of the analog computer theory group.

Table 1B includes a listing of the type of recording equipment required for each problem. Strip chart recorders are priced between $500 to 1,000 per channel. At least two channels are necessary for problems so designated. X-Y recorders are priced in the $1500, and above, range. Oscilloscopes can be used in place of either type of recorders. The regular 7-inch scope can be purchased in the under-$500 range, but this size is quite small for classroom use. A 17-inch television type oscillograph is available for approximately $1500. Repetitive operation must be available on the computer if an oscilloscope is to be used. Table 5 lists some representative manufacturers of recording gear.

Table 6 lists some manufacturers of multipliers and function generators. Servomultipliers can be had for about $1500 and up. They normally permit multiplication or division of each of five variables by one other. Electronic multipliers are available for about $500 per multiplication or division, and usually come in groups of two or three. They are completely flexible in operation, unlike the servomultiplier. Electronic function generators in the price range of $1000 per channel are available. Servomultipliers which are also capable of function generation are readily available at a somewhat higher price than those capable only of multiplication or division.

Summary

It is possible for one to procure an effective analog computer for classroom demonstration for as little as $400-500, if purchased in kit form. However, a much more reasonable figure for a complete set-up, particularly for chemical-type problems, would be $5,000+. This would include a 10-15 amplifier computer, 2 channels of multiplication, one channel of function generation, and the proper recording apparatus. Such a unit would be invaluable for classroom demonstration of the solutions of linear and nonlinear differential equations, the dynamics of chemical processes, chemical kinetics, and automatic control action and its effect on process dynamics.

Table 5. Representative manufacturers of recording equipment.*

A. Oscilloscopes
1. Allen B. DuMont Laboratories, Inc.
760 Bloomfield Ave.
Clifton, New Jersey
2. Heath Company
Benton Harbor, Michigan
(Manufacturers of Kits)
3. Hewlett Packard Company
275 Page Mill Road
Palo Alto, California
4. Tektronix, Inc.
P. O. Box 831
Portland 7, Oregon

B. Strip chart recorders (multivariables vs. time)
1. Benson-Lehner Corp.
11930 W. Olympic Blvd.
Los Angeles 64, California
2. Brush Electronics
3405 Perkins Avenue
Cleveland 14, Ohio
3. Century Electronics & Instruments, Inc.
1333 N. Utica
Tulsa 10, Oklahoma
4. Electronic Associates, Inc.
Long Branch, New Jersey
5. Minneapolis-Honeywell Regulator Co.
Heiland Instruments Division
5200 East Evans Avenue
Denver 22, Colorado
6. Offner Electronics, Inc.
5326 Kedzie Avenue
Chicago 25, Illinois
7. Reeves Instrument Corporation
East Gate Blvd., Roosevelt Field
Garden City, L. I., N. Y.
8. Sanborne Company
39 Osborne Street
Cambridge 39, Massachusetts
9. Varian Associates
Instrument Division
611 Hansen Way
Palo Alto, California

C. X-Y Recorders (Most of these are also convertible to function generators)
1. Electronic Associates, Inc.
Long Branch, New Jersey
2. Houston Instrument Corporation
1717 Clay Avenue
Houston 3, Texas
3. Librascope Incorporated
808 Western Avenue
Glendale, California
4. Link Aviation, Incorporated
Binghamton, New York
5. F. L. Moseley Company
409 No. Fair Oaks
Pasadena, California
6. Societe d'Electronique et d'Automatisme
138 Boulevard de Verdun
Courbevoie (Seine)
France

** No attempt has been made here to give a complete listing of manufacturers of recording equipment. Such a list would be too long for this paper. For more complete listings, the reader is referred to the "Electronic Buyer's Guide & Reference Issue" of* Electronics, *June 1959-Mid Month Issue. Also, June 1959 issue of* Computers & Automation.

Table 6. Manufacturers of multiplication & function generation equipment.
1. Berkeley Division, Beckman Instruments, Inc.
2200 Wright Avenue
Richmond 3, California
2. Donner Scientific Company
Concord, California
3. Electronic Associates, Inc.
Long Branch, New Jersey
4. G. A. Philbrick Researches, Inc.
285 Congress Avenue
Boston 16, Massachusetts
5. Radio Corporation of America
Front and Cooper Streets
Camden, New Jersey
6. Reeves Instrument Corporation
East Gate Blvd., Roosevelt Field
Garden City, L. I., New York

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Photo courtesy Food Machinery & Chem. Corp.

HOWARD A. SOMMERS

Soda ash from trona

Modern soda ash trend is to the production of the soda ash from the less costly, and practically unlimited supplies of trona

FOOD MACHINERY AND CHEMICAL CORPORATION recently announced expansion of its soda ash-from-trona plant at Westvaco, Wyoming, to 475,000 tons/yr. (*1*). This is of considerable importance for manufacturers and users of this mass-produced "staple", the third largest chemical produced tonnage-wise. Progress since 1953 in the development of this source of soda ash has vast future significance.

Until 1949, about 94% of the soda ash produced in this country (*3, 4*) was manufactured from common salt and limestone by the ammonia-soda process, invented in the early 1800's (*2*). A list of all of the producers of ash in the United States is shown in Table 1. In the chemical industry rarely has any major process stood unchallenged for nearly a century. Now a way has been found to make a superior product at roughly half the capital investment and substantially lower production cost.

In 1957, about 13% (3) of the ash produced in this country came from the natural brines of Searles and Owens Lakes and from Wyoming trona. Of this 13% (697,000 tons) about one-third came from the plant of Intermountain Chemical Co. (90% owned by Food Machinery), from the refining of trona, sodium sesquicarbonate—$Na_2CO_3 . NaHCO_3 . 2H_2O$.

The ammonia-soda process uses simple raw materials found in many places—salt, limestone, and coke. The process is straightforward, but does require quite precise control and is economical only on a large scale basis. The selling price of ash has not kept pace with the increased cost of most other chemicals, with the result that today the high capital cost (*5, 9*) relative to profit, explains why no new ammonia-soda plants have been built since 1935. Until Westvaco built its pilot plant in 1947, and the 300,000 ton/yr. refined ash plant in 1953, no new ammonia-soda ash producer had entered the industry since 1912.

For many years profits from existing, more or less completely written-off ammonia-soda plants were quite poor, and with no prospect of reaching reasonable earnings without a substantial price increase (this has not materialized). Technologically, the ammonia-soda process has slowly and steadily improved over many years. It is safe to state that production costs cannot be materially improved by any change in process or equipment at this time (*13, 14*). Before 1935, plants represented less than $10,000 invested/daily ton of capacity (*9*), which now have been nearly completely depreciated. These plants, if duplicated today, are estimated to cost $30-35,000/daily ton of ash capacity (*1, 9, 13*)—approximately double the cost of the Westvaco plant (*5, 7*). The return on a new ammonia-soda plant, at today's selling price ($31/ton for light ash) would be something less than 2%, after taxes.

Consumption of ash is increasing at the rate of about 170,000 tons/yr. (*3, 11*)—the situation confused by the use of caustic to replace ash when caustic is "long". Thus sooner or later, new production capacity will be required but this will have to come from processes other than ammonia-soda. This explains why the major ash producers are actively studying the ash-from-trona situation today; why Diamond Alkali is currently exploring the Wyoming trona deposits (*1*) and why at least four companies have substantial leased holdings adjacent to the Westvaco plant.

The chlorine-caustic imbalance in recent years has diverted considerable ash (once made into caustic) to other uses (*11*). Rather than dump the surplus caustic into the Gulf at considerable expense, Dow has entered the soda ash business in Texas by carbonating caustic with flue gas. This downgrading of caustic is of course justified under the circumstances but with conventional bookkeeping, where the cost of chlorine cell operation is divided about equally between caustic and chlorine, the cost of producing such ash is likely to be high.

Much of the gain in chlorine-caustic soda capacity has been at the expense of lime-soda caustic, made in constantly decreasing quantities (8% in 1957) and thus releasing ash for other uses.

Average production cost of the

ammonia-soda producers, with today's depreciated plants, is estimated by the writer at about $20/ton; the cost of production from Wyoming trona is estimated to be substantially lower than this. With prevailing relatively-low freight rates, Wyoming ash can be shipped to eastern, southern, and western markets and can compete with the producers there, as is being done today.

History of Wyoming trona deposits

Geologists have offered many theories of the formation of the trona deposits, but without general agreement. The trona deposits lie in the geologically ancient Lake Gosiute that covered an area of some 30,000 sq. mi. extending from Wyoming into Utah and Colorado (*6*). During the Eocene period, this lake was an impressive body of water; it lay near sea level and abounded with plant, animal, and bird life. Natural waters entering the lake carried heavy loads of salts, and evaporation eventually saturated its water with sodium salts. Trona is believed to have come from the reaction of solutions of carbonates of lime on analcite beds, and from the leaching of alkaline silicates by surface waters, followed by concentration of sodium carbonate in the lake, and finally the deposit of the salts.

Sodium carbonate brine in shallow wells was discovered at Green River, Wyoming, (*4, 6, 12*) before 1900. In 1907 the Western Alkali Corp. used the brine from 13 wells, partially evaporating it and crystallizing sal soda, $Na_2CO_3 \cdot 10H_2O$. The operation lost money and was abandoned about 1920. Similar brine has also been found at Eden, some 36 miles north of Green River.

In the summer of 1938, the Mountain Fuel Supply Co., while drilling for oil 18 miles west of the town of Green River, to a depth of 3169 ft., found not oil or gas, but a vast deposit of trona, sodium sesquicarbonate $-Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ at a depth between 1490 and 1510 ft. Following this discovery, the Union Pacific R.R. drilled five core holes during 1940-1942 to determine the limits of the ore body. These holes were drilled some 1600 ft. below the surface and all of them found trona, varying from 7 to 11 ft. in thickness. The boundary limits of the deposit were not defined.

In 1947, Westvaco drilled four additional holes and confirmed the findings of Mountain Fuel and Union

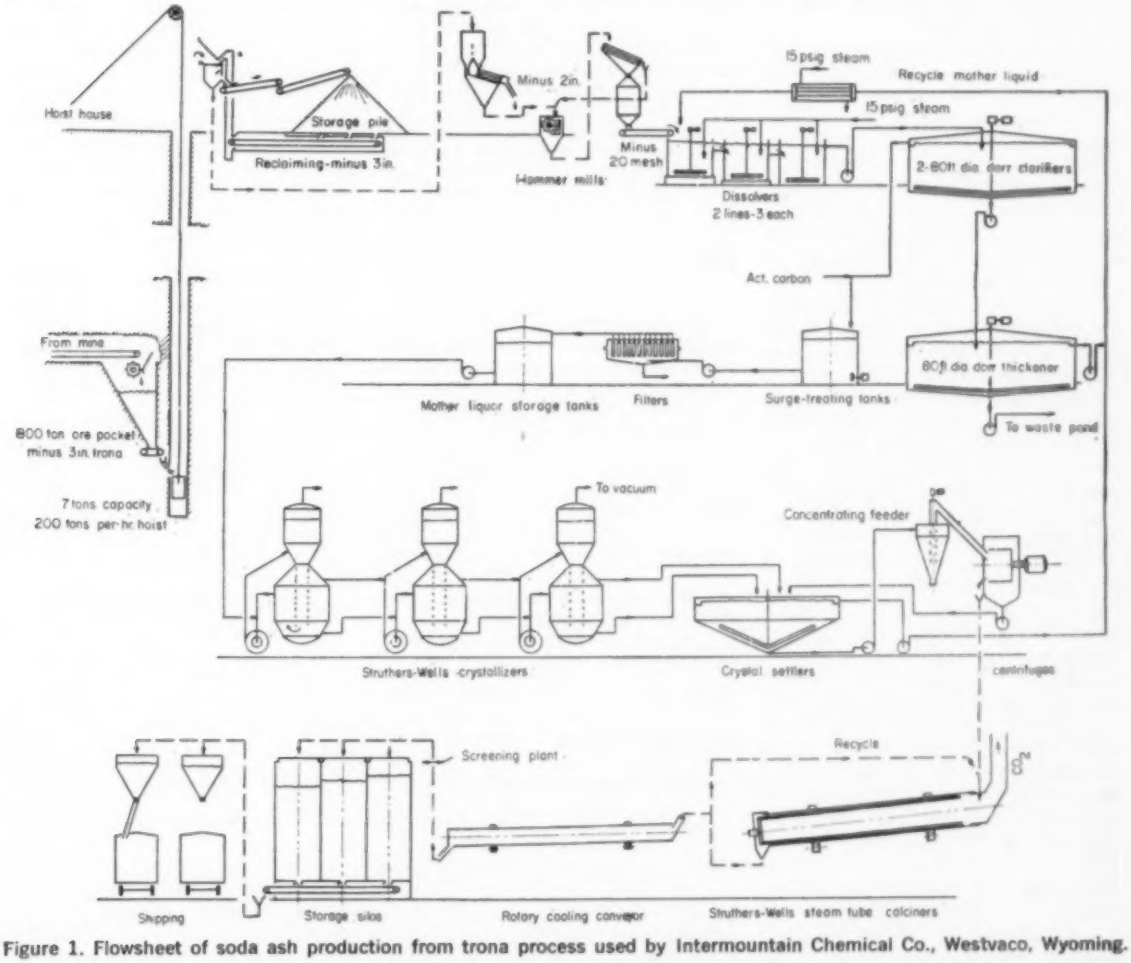

Figure 1. Flowsheet of soda ash production from trona process used by Intermountain Chemical Co., Westvaco, Wyoming.

Pacific, proving up a total of about 30 sq. mi. containing some 250 million tons of trona, sufficient to produce 175 million tons of refined soda ash.

As of the end of 1958, a total of about 20 holes, drilled by Mountain Fuel, Union Pacific, Potash Company of America, Westvaco, and others, had proved up more than 50 sq. mi. of trona, but without outlining the limits of the ore body.

The main trona deposit is intimately associated with oil, bentonite, and clay shales of the Green River formation. The trona deposit is mostly dry and free of water, but occasionally considerable flow of water is encountered, and small pockets of gas frequently found make good ventilation mandatory (*6, 7*). Many thin seams of trona varying in thickness from a fraction of an inch to 8 in. or more, lie above the main deposit at the 1500-ft. level, and two thin seams lie a little below it. In general there is a total of some 50 ft. of trona, but unfortunately only the main 7- to 11-ft. seam is commercially minable by present techniques.

Westvaco first proposed to drill holes to the main trona bed and pump a trona brine to be concentrated and refined, as Western Alkali Corp. did originally. But trona is soluble in water only with great difficulty and the capacity of a "well" was very little. This approach was therefore quickly abandoned in favor of direct mining methods similar to those used for coal and salt (*6, 7*).

In 1946 a 12-ft. diam. concrete-lined shaft (No. 1) was sunk to the 1500-ft. level, the mine partially developed, a hoist installed, and a small pilot plant erected to crush, calcine, and screen the natural ore. As the insolubles in the trona are not removed (averaging about 6%), the final product of this operation is crude ash satisfactory for many applications not requiring conventional refined ash.

The development of the mine and the operation of the crude soda ash plant taught the operators much about this unusual deposit, the best mining system, ventilation required to remove gas infiltration, and the solution of many other problems (*6, 7*).

The room-and-pillar method is used with ordinary coal-mining machinery, modified to handle the heavier and more abrasive trona. The rooms are normally about 8-ft. high (the exact thickness of the trona deposit), 20-ft wide, and 250-ft. long—on 65-ft. centers. Pillars are extracted on the retreat by a system of split pillars and a protective fender between the cave and the mining face. Overall extraction is in excess of 75% of the available trona. The mine is "trackless" to take advantage of the saving in hauling costs by the use of belt conveyors wherever possible.

In 1950, a plant of 30,000 ton/yr. capacity was designed and built, with provisions for easy expansion later to at least twice this capacity.

The process used by Westvaco is shown on Figure 1, (*5, 8, 15*). Trona from the working faces is delivered by shuttle car to a 36-in. conveyor belt system several miles long, designed to handle in excess of 350 ton/hr. running from fines to lumps a foot long. The belt discharges into a permanently positioned 21 × 60 in. single-roll toothed crusher, elevated over a 36-in. drag conveyor. This receives the *minus* 3-in. trona and conveys it some 60 ft. into an underground storage pocket of 800-tons capacity near the bottom of No. 2 shaft.

The ore storage pocket discharges into the hoisting skips through an apron feeder, timed to fill automatically-weighed hoppers holding the exact load capacity of the skips, 6 tons. The operation is entirely automatic but can be controlled manually if desired.

The No. 2 shaft, 14-ft. diam. concrete-lined, some 1100 ft. west of No. 1 shaft, contains the two counterbalanced skip hoists. These shafts are near surface operations. A third shaft, No. 3, 18-ft. diam. also concrete-lined, was installed in 1956 and is located 1¼ miles south of the plant to provide additional ventilation. No. 3 is "downcast", providing air for the entire mine operation. No. 2 is the production and exit air shaft. A fresh air split is carried to No. 1 to permit its use for transporting men and materials in and out of the mine.

Crushing and screening. As shown in Figure 1, most of the ore is passed directly to the hammermills, only a small portion going out to the stockpile. The storage is necessary as the plant operates continuously but the

H. A. Sommers is with Pennsalt Chemicals, and also has his own consulting practice in Allentown, Pa. As chief engineer for Food Machinery and Chemical for several years, Sommers was project manager of a soda ash plant from natural trona at Green River, Wyoming, believed to be the only one of its kind. Sommers, who holds two patents, has authored several articles for CEP. The most recent was based partly on travel he had done in Europe in connection with chlorine plant rehabilitation.

Table 1. Soda ash plants in the United States.

Company	Location	Year Built	Type of Plant	Daily Capacity[1]
Solvay Process Div.	Syracuse, N. Y.	1881	Amm. Soda	2700
Solvay Process Div.	Detroit, Mich.	1898	Amm. Soda	2650
Solvay Process Div.	Baton Rouge, La.	1935	Amm. Soda	2150
Columbia-Southern Chem.	Barberton, Ohio	1900	Amm. Soda	1700
Columbia-Southern Chem.	Corpus Christi, Tex.	1934	Amm. Soda	1500
Columbia-Southern Chem.	Keeler, Calif.		Nat. Brine	215[2]
Wyandotte Chemicals Corp.	Wyandotte, Mich. (North)	1893	Amm. Soda	1900
Wyandotte Chemicals Corp.	Wyandotte, Mich. (South)	1927	Amm. Soda	900[3]
Diamond Alkali Co.	Painesville, Ohio	1916	Amm. Soda	2200
Olin Mathieson Chem. Corp.	Saltville, Va.	1894	Amm. Soda	1050
Olin Mathieson Chem. Corp.	Lake Charles, La.	1934	Amm. Soda	1500
Intermountain Chem. Company	Westvaco, Wyo.	1953	Trona	1200[4]
West End Chemical Co.	West End, Calif.		Nat. Brine	530[5]
American Potash & Chem.	Trona, Calif.	1920	Nat. Brine	800[5]
Kaiser Aluminum & Chem.	Lone Pine, Calif.		Nat. Brine	35
Dow Chemical Co.	Freeport, Texas		Caustic Carbonation	325

[1] *Daily capacity in short tons.*
[2] *From Owens Lake brines.*
[3] *Not operating.*
[4] *To be increased to 1350 in 1959.*
[5] *From Searles Lake brines.*

mine usually only two shifts/day, and 5 or 6 days/wk, and as the mine is being continuously expanded, the amount of trona mined each day is not fixed.

The ore is reclaimed from storage by means of a tunnel and belt under the pile in conventional fashion. Considerable bulldozing is necessary as the ore "sets up" from moisture either from wetting down in the mine or from the atmosphere.

The *minus* 3-in. trona is crushed and screened to *minus* 2-in., the feed to the natural ash pilot plant nearby. Minus 2-in. is also bagged and sold as "Sultron".

Hammermills crush the trona to *minus* 10-mesh (approx.) and discharge it over Tyler screens, the *minus* 20-mesh passing through to the storage bins. The *plus* 20-mesh is recycled through the mills.

Dissolving. The *minus* 20-mesh trona is fed to two lines of 12-ft. diam. well-agitated dissolvers (three in series) by pan feeders. Mother liquor from the settlers is reheated with make-up water to 200° F (the boiling point at the plant elevation of 6200 ft.), and by direct 15 lb./sq. in. steam. This puts the trona in solution. The two dissolver lines feed 80-ft. diam. Dorr clarifiers and these in turn feed into a similar Dorr thickener. Waste from this contains almost all of the insoluble material (about 6% of the trona mined) and is pumped to a waste pond.

Filtration. The overflow from the clarifiers is reheated and pumped into surge-treating tanks where a measured quantity of activated carbon is added to remove organic and other trace impurities that would cause foaming in the crystallizers. This reasonably clear liquor is then passed through a battery of Sweetland filters, precoated in conventional fashion, and "polished" (*15*). The stream of clear and pure feed liquor is again split into two lines, and after passing through surge tanks, goes to a three-vessel Struthers-Wells vacuum crystallizer system of conventional design.

On cooling the liquor to about 140° F, needle-shaped sesquicarbonate crystals form which grow in size as they proceed, in a 20-30% slurry, through the three units to settlers. The thick slurry from the settlers is pumped to concentrating feeders and thence to Baker-Perkins continuous centrifuges where the crystals are dried to about 7% moisture.

Calcining and screening. The crystals from the centrifuges are conveyed to Struthers-Wells steam-heated calciners. These are the largest made and are more or less standard in the ammonia-soda industry. A part of the discharge is recycled to prevent caking. The $Na_2CO_3.NaHCO_3.2H_2O$ is reduced to Na_2CO_3 by driving off the CO_2 and H_2O. Unlike the ammonia-soda process, this plant has no use for the large quantities of high purity CO_2 that go to waste.

The final product has a density of about 50 lb./cu.ft. as compared to standard light ash of about 35. It is of excellent chemical quality and flows more freely than ammonia-soda light ash. The ash from the calciners is simultaneously transported and cooled in a rotating water-cooled conveyor to the screening plant. Here the ash passes over conventional screens to separate the various grades. Dense ash is produced conventionally by adding water to the semidense ash in a "cement mixer" type of densifier. The crystals grow, and after drying in a Struthers-Wells unit (same as the calciner), have a bulk density of 60 lb./cu.ft.

Shipping arrangements are modern. Overhead storage bins are located directly above the tracks. Two weeks' storage of ash is provided in six concrete silos of conventional design.

Solution mining of trona

Westvaco's original plan to obtain trona as brine was abandoned in favor of direct mining, as we have noted. In 1956, investigation of this problem was resumed (*1, 10*). Solution *in situ* is difficult because of the dense nature of the deposits, horizontally disposed as they are in thin layers, the relative insolubility of trona in hot or cold water, and the insoluble material (clays and organic matter) intimately mixed throughout the ore. However, since direct mining recovers only some 75% of the main 7 to 11-ft. deposit, solution mining that could tap, say 1/3 of the 30-ft. total of trona, might be worthwhile.

If solution mining proved impractical, a compromise might be the flooding of a worked-out mine, (*16*). If a *saturated* solution could be obtained, dissolving of trona in the ground could replace mining, hoisting, crushing, screening, and dissolving operations at considerable cost saving. If only a weak, less-than-saturated, solution were recovered, the process used to make ash would be vastly different.

Possible refining processes

Many ways exist to produce soda ash from trona (ore and/or brine). Various sodium compounds can be produced in intermediate steps by manipulation of brine compositions, temperature, and pressure:

1. Sesquicarbonate.
2. Anhydrous carbonate.
3. Monohydrate.
4. Bicarbonate.

On calcining (or drying), any of these compounds yield soda ash having various physical properties—crystal size, shape, and resulting bulk density. The first produces crystals of excellent flow characteristics and a semidense ash (*15*); the second, a "super dense ash"; the third, dense ash directly; and the fourth, bicarbonate and conventional light ash.

Conclusions

Because of the low profit from soda ash as made by the old, well-established ammonia-soda producers and the high cost of new plants employing this process, the future trend will be to ash made from Wyoming trona. Here the capital cost is only half that of conventional ammonia-soda plants, and production cost is estimated to be substantially lower. Trona is available in practically unlimited quantity. Ash production is currently estimated at about 80% of capacity and growing at the rate of 170,000 tons/yr. Excess electrolytic caustic is forcing reduction of lime-soda caustic, releasing ash for direct sale. But in 1957, only 8% of the total caustic produced was from lime-soda.

Elimination of all lime-soda caustic production will delay, but not solve, the potential problem of caustic imbalance and delay for a few years the ultimate ash shortage. This chlorine-caustic imbalance is forcing a reversal of the caustic-from-ash situation and one producer is now making several hundred tons of ash per day from caustic. Current relatively low freight rates on soda ash make it possible to reach most parts of the U. S. competitively from Wyoming.

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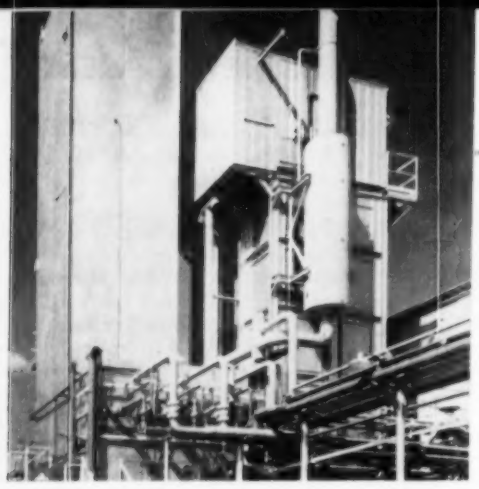

Typical tonnage oxygen plant owned and operated by Air Products for chemical producer.

A. C. T. Hsu and Clyde McKinley

Purify liquid oxygen via adsorption

Experimental data cast new light on significance of pressure, concentration, and nature of contaminant. Of special interest: influence of adsorbates on each other during simultaneous adsorption.

In low temperature purification treatment of process streams, the design engineer must take into consideration the complications introduced by possible interference by the carrier stream or by other interfering adsorbates. He must be concerned with the departure from ideal behavior of fluid systems under cryogenic conditions. Few basic data, directly applicable to process design or to performance evaluation of low temperature adsorbers, have been made public. The Russian publications (*3, 4, 5, 8, 11*), which originally described the silica gel adsorber application to air separation plants, present some design and performance behavior restricted to acetylene. Kerry (*6*) has listed some practical rules and considerations for adsorber design.

This article presents and discusses some experimental data on the behavior of adsorbent beds, with dynamic conditions receiving the major attention. The data presented illuminate to some extent the significance of such factors as pressure, concentration nature of contaminants, and, especially, influence of adsorbates upon each other during simultaneous adsorption.

Oxygen Plant Application. Utilization of adsorbers under several possible process conditions is illustrated in Figure 1 for a medium pressure air separation process. At the highest system pressure, water is removed in silica gel, alumina or other adsorbent drying media. The dry air is cooled by heat exchange with the low pressure nitrogen gas. At a reduced temperature, this air stream is in part expanded through an engine to obtain refrigeration. Before entering the expander, this air may be passed through an adsorbent bed to remove carbon dioxide and the less volatile hydrocarbons, such as acetylene. Such an adsorber would be an alternate to the chemical removal of carbon dioxide.

Adsorbers may also be located in the cold air stream entering the high pressure column. Such adsorbers have special significance from the standpoint of plant safety if the impurities remain in solution up to this point, but exceed their solubility limit if allowed to continue with the process stream. The solubility limit may be exceeded through the concentration of materials in the liquid phase as a result of distillation process or due to reduction in temperature at subsequent process points.

In the usual cycle, the air stream continues into the high pressure column where the contaminants will be concentrated in the liquid bottoms. By the use of adsorbers in this crude liquid stream, it is purified before it enters the low pressure column.

The oxygen product may be further purified by passage through adsorbers for removal of final traces of carbon dioxide or other solutes which have escaped previous removal devices.

Experiments have been selected to provide data and to illustrate adsorber behavior under actual process conditions such as prevail in the crude liquid oxygen adsorbers of Figure 1.

Experimental procedure

The apparatus used in this investigation is shown schematically in Figure 2. The assembly is relatively simple, consisting of the pure gas and gas mixture supply, the experimental adsorber columns and cooling coils, the analytical instrumentation and recording equipment, and the necessary interconnecting piping and valving.

The adsorber columns, which varied in length from 4 in. to 100 in., were made of ¾-in. copper tubing, packed with well-sifted 48/65 mesh silica gel. In order to minimize the holdup of the liquefied mixture during a run, 1/16-in. stainless steel tubing was used to interconnect the parts immersed in the liquid oxygen bath.

The data which will be presented later are principally for silica gel Grade 01 and Grade 03 supplied by Davison Chemical Co. These gels are quite similar in characteristics (*1*):

Surface area by nitrogen adsorption	832 sq. m./g.
Average pore size	22 Å
Average bulk density	45 lb./cu. ft.

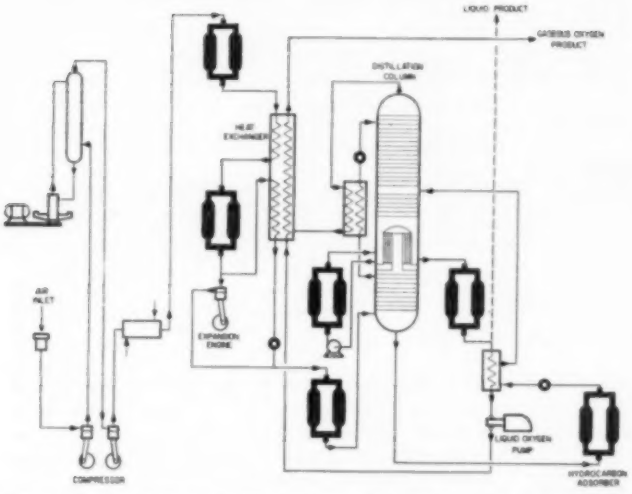

Figure 1. Adsorber application in medium pressure air separation process.

Density of individual particles 75 lb./cu. ft.

Since it is well known that the surface area and pore volume, hence the capacity, of silica gel are sensitive to temperature (*9*), the adsorbents were given substantially the same reactivation treatment prior to each run. The reactivation was carried out by maintaining the adsorbent column at approximately 350°F for at least 15 hours, and thereafter the column was flushed with nitrogen at the elevated temperature for about one hour before being connected to the adsorption assembly. These reactivation conditions, approximating those adopted in air plants, were found to be adequate in enabling us to reproduce the capacity values of the adsorbents.

In a typical run, a mixture of low molecular-weight hydrocarbon in oxygen was led from the mixture cylinders to the cooling coils and reservoir which were maintained at the normal boiling point of liquid oxygen. When the condensate filled both the coils and the reservoir, the needle valve leading to the adsorbent column was opened slightly to allow the liquefied mixture to flow slowly upward until the liquid level reached the top of the adsorbent column and established the operating pressure of about 100 lb./sq. in. The valves after this point were then opened slowly to build up the pressure desired in the infrared analyzer and rotameter. The setup was ready and the run was started by opening the toggle valve after the rotameter. It may be pointed out here that the build-up of the pressure and liquid level in the different stages was so adjusted as to avoid any possible surge of the liquefied mixture through the packed adsorbent.

With a view to examining the rate processes involved in liquid-phase dynamic adsorption, sectional columns, as detailed in Figure 3, were used in several runs. The adsorbent to be studied was located in these sectional columns placed in series, with sample taps between each section. The sample taps lead to a common manifold which, in turn, leads to the analytical equipment. In the same low-temperature bath with the columns are the two sets of cooling coil-reservoir combinations connected in parallel for conditioning the mixtures to be studied. Mixture I, entering the system through one coil, can be replaced by Mixture II through the valves indicated at the base of the cooling coils. Thus the columns can be subjected alternately to streams of different compositions or containing different contaminants.

The superficial mass flow rate in the experimental runs ranged from 9 to 75 lb. moles/hr./sq. ft., dependent on the column and hydrocarbon used.

Analyses were made by infrared [for details of method see (*10*) and chromatography].

Experimental results

A chart record such as was obtained from a *typical experimental run* is shown in Figure 4. The adsorbate concentration in the effluent is plotted as a function of time. The dotted line shows the inlet concentration, which remains constant. The effluent concentration remains at zero until the "break through," t_B, is reached. The effluent concentration continuously increased until it became equal to that of influ-

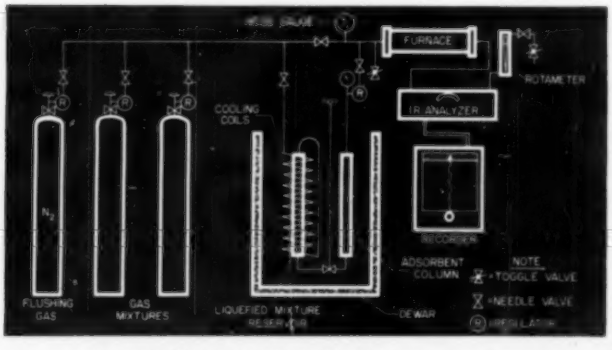

Figure 2. Experimental apparatus.

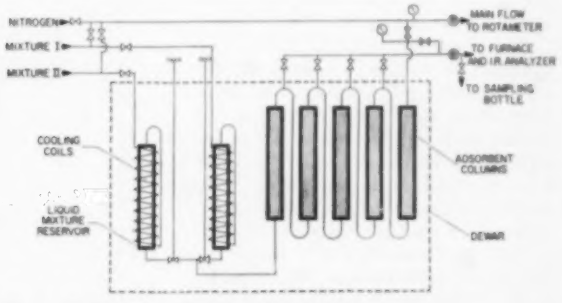

Figure 3. Experimental adsorber details.

ent, indicating that the bed became saturated with the adsorbate. The time at this point is designated as t_B. The horizontally shaded area is proportional to the saturated capacity of the column. The vertically shaded area represents the relative amount of adsorbate which escapes from the adsorbent bed during passage of the wave front out of the bed.

The *adsorption capacity* is calculated from the saturation time, t_B, the adsorbate concentration in the influent mixture, the flow rate of the mixture, and the amount of adsorbent in the column. The capacity values thus obtained represent essentially the equilibrium capacity because of the relatively long adsorbent column, small adsorbent particle size, and low flow rates used in experimental runs. This has been confirmed by comparing the results obtained with data from sectional columns.

The recording of a typical run in a sectional column is shown in Figure 5. The breakthrough time for each section is as indicated. For instance, when the adsorbate concentration in the effluent after section 1 reached about 5 per cent of that of the influent, the valve for sample tap 1 was closed and the valve for sample tap 2 was opened. The run was continued until three or four of these waves were obtained, the last breakthrough being recorded until saturation was reached.

The capacities computed for each section were generally in good agreement with one another (except section 1) and with those obtained by using long single-section columns. These capacity values are equal to the corresponding equilibrium capacities determined by the static methods under the same temperature, concentration, and total pressure.

Wave front length. It is well known (2) that the wave front length of an adsorbent column may be determined by plotting the cumulative breakthrough time for each section against the cumulative length of the successive sections, the intercept at zero time indicating the portion of the column occupied by the wave front under the operating conditions.

The wave front length in cases of dynamic adsorption is specific for given operating conditions. The wave front shape is affected by interrelated factors such as the nature of the adsorbate-adsorbent system, concentration of adsorbate in the carrier fluid, flow rate of carrier fluid, temperature, pressure in case of gas mixtures, adsorbent particle size, and perhaps, the length/diameter ratio of the adsorber. In an experimental bed in a cryostat, it is not uncommon to experience a wave front as short as ¼ in. At present, a detailed treatment of this subject is beyond the scope of this presentation. Engineering designs for low temperature applications are made to minimize the portion of the bed occupied by the wave front.

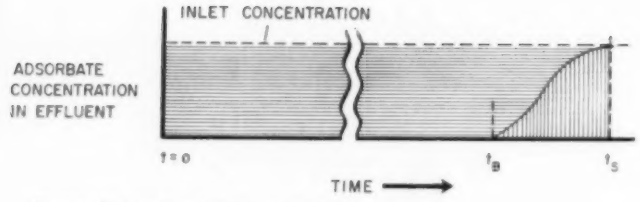

Figure 4. Single-column run record.

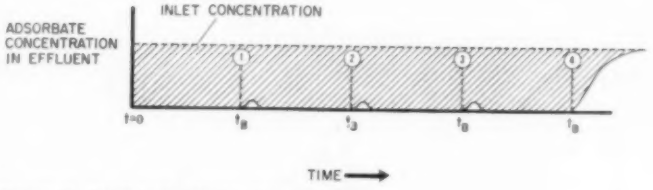

Figure 5. Sectional-column run record.

Light hydrocarbon adsorption

The adsorption, by silica gel, of methane, ethane, and ethylene from liquid oxygen proceeded experimentally in accordance with the general pattern shown in Figure 4 and Figure 5.

The experimental results for the adsorption of these hydrocarbons under various conditions are summarized in Table 1.

A Freundlich-type plot for the adsorption of methane, ethane, and ethylene is shown in Figure 6. Within the concentration ranges covered, the capacity of silica gel for ethane and ethylene is, in the log-log plot, a linear function of their concentration in the liquid mixture. These capacities may be represented by the following expressions:

For ethane:

$$\log N' = 0.729 \log p - 4.113$$

For ethylene:

$$\log N' = 0.148 \log p - 1.400$$

Where: N' = adsorptive capacity of silica gel (lb. of ethane or ethylene per lb. of silica gel).

p = ppm of ethane or ethylene in liquid oxygen.

Extrapolation may be made, either graphically or analytically, to a limited extent, to estimate the capacity of silica gel at liquid oxygen temperature for these hydrocarbons outside the experimental concentration ranges.

With respect to the selectivity of

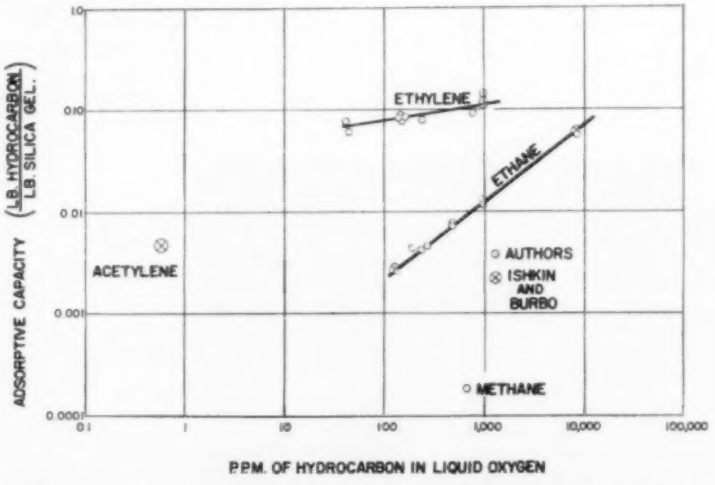

Figure 6. Silica gel capacity for ethane, ethylene, and methane at LOX temperature.

silica gel, it may be noted that silica gel has a much higher capacity for ethylene than for ethane. Reasoning from the relative degree of unsaturation, silica gel is expected to have the same or even higher capacity for acetylene, compared at the same concentration. The data of Ishkin and Burbo (*4*) on acetylene-silica gel are also shown in Figure 6. A quantitative comparison should not be attempted with these data in view of the low concentration of acetylene, less than one ppm, used in the Ishkin-Burbo experiments, and their relatively high mass flow rates. Nevertheless, the results clearly indicate that silica gel is highly selective for removal of the more dangerous acetylene and olefins among the hydrocarbons in crude liquid oxygen.

Silica gel has proved to possess an extremely low capacity for methane, which would be readily displaced by other hydrocarbons occurring in normal crude liquid oxygen. Fortunately, methane is soluble in liquid oxygen in almost any proportion, and the passage of trace quantities of methane through hydrocarbon adsorbers does not pose a serious hazard in safe operation of air plants.

As to the effect of the liquid medium on the capacity of silica gel, the results in Table 1 indicate that there was essentially no difference in the amount of ethylene adsorbed by silica gel whether the olefin was carried in liquid oxygen or in a liquid mixture of 40% oxygen–60% nitrogen. This might be attributed to the fact that the ethylene concentration used was considerably below its solubility in both liquid media and that there was probably little difference in the interference exerted by liquid oxygen and nitrogen at the operating conditions. It should be noted that the gel capacities listed in Table 1 are substantially lower than would be the case in the absence of the oxygen-nitrogen liquid medium.

As long as the carrier fluid, *i.e.* oxygen or 40% oxygen–60% nitrogen, remained as liquid, a variation of pressure between 45 to 135 lbs./sq. in. abs., had no appreciable effect on the adsorption of ethane and ethylene by silica gel. This generalization probably applies to other hydrocarbons in crude oxygen. It is expected, therefore, that there would be no shift of adsorbate distribution on silica gel in the event of minor pressure fluctuations inside hydrocarbon adsorbers.

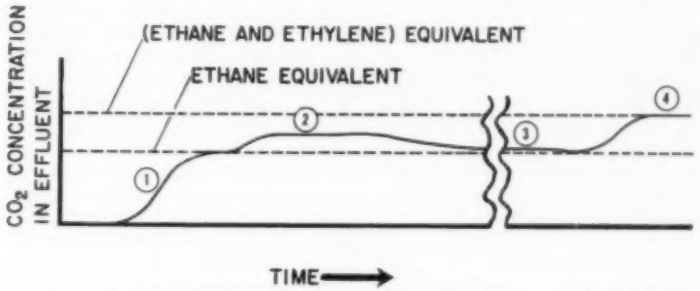

Figure 7. Idealized chart record for simultaneous dynamic adsorption by silica gel of ethane and ethylene from LOX.

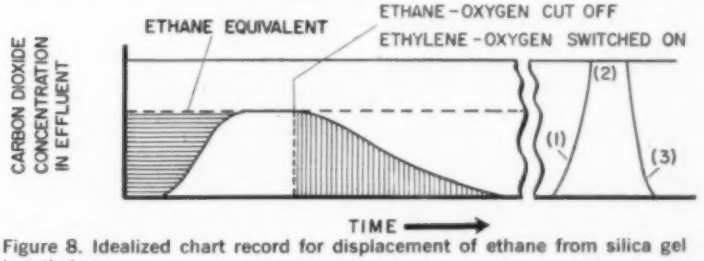

Figure 8. Idealized chart record for displacement of ethane from silica gel by ethylene.

Simultaneous adsorption

In order to gain understanding experimentally of the interrelationship of two adsorbates during their simultaneous dynamic adsorption, some runs were made with a solution containing ethane and ethylene. The mixture contained 287 ppm of ethane and 261 ppm of ethylene in 40% oxygen–60% nitrogen. The experimental column was 8 inches in length, the effluent was continuously monitored for carbon dioxide content, following a combustion furnace. Figure 7 shows the carbon dioxide content of the effluent as a function of run time. At the points on the curve marked 1 through 4, samples were withdrawn from the stream before it entered the furnace and analyzed chromatographically for their ethane and ethylene contents. The infrared record for CO_2 showed that ethane broke through the column shortly before point 1 but at this point no ethylene was found in the effluent.

After the gel bed was entirely satu-

Table 1. Silica gel capacity for methane, ethane, and ethylene at liquid oxygen temperature.

Adsorbate	Carrier Liquid	Concentration of Adsorbate in Carrier (ppm)	Adsorbent (Davison Silica Gel)	Adsorptive Capacity of Adsorbent (lb. Adsorbate per lb. Adsorbent)	Total Pressure (lb./sq. in. abs.)
Methane	40% Oxygen-60% Nitrogen	575.0	Grade 01	0.000220	95
Ethane	Oxygen	132.0	Grade 01	0.00289	121
		135.0	Grade 01	0.00293	120
		132.0	Grade 03	0.00284	135
		492.5	Grade 01	0.00667	127
		492.5	Grade 01	0.00772	120
		495.0	Grade 03	0.00740	100
		8884.0	Grade 01	0.0539	129
		8884.0	Grade 01	0.0571	124
		8884.0	Grade 03	0.0584	135
Ethylene	Oxygen	47.5	Grade 03	0.0747	45
	"	51.8	Grade 03	0.0679	95
	"	156.0	Grade 01	0.0888	100
	"	159.0	Grade 03	0.0861	135
	"	154.0	Grade 03	0.0841	95
	"	154.0	Grade 03	0.0894	50
	40% Oxygen-60% Nitrogen	261.0	Grade 03	0.0877	110
	Oxygen	798.0	Grade 03	0.0960	95
	"	995.0	Grade 01	0.112	123
	"	995.0	Grade 01	0.109	100
	"	995.0	Grade 01	0.121	120

rated with ethane, this adsorbed ethane was partially displaced by ethylene. This raised the concentration of ethane leaving the bed to a level above that of the entering stream. This is indicated by the CO_2 level at point 2, at which no ethylene was detected in the effluent. The carbon dioxide concentration was due entirely to ethane and was higher than that which corresponds to ethane in the incoming gas concentration.

As the run continues, the hydrocarbon in the effluent gradually drops as equilibrium throughout the bed is continuously reestablished. At point 3 there was still no ethylene in the effluent and the carbon dioxide equivalent of the ethane leaving the column was slightly greater than that of the ethane entering.

Eventually, ethylene broke through the column and the silica gel reached its simultaneous saturation capacity for the two hydrocarbons. This occurred at point 4 where the ethane and ethylene contents of the effluent were analytically found to be identical with those of the influent.

The capacity of the silica gel for ethane, computed from its breakthrough time was 0.00298 lb. ethane per lb. silica gel as compared to 0.004 interpolated from Figure 6 for 287 ppm ethane in oxygen. The low capacity was probably mainly due to the short length of the column which was not adequate to handle the ethane-silica gel system under the operating conditions.

The capacity of silica gel for ethylene calculated on the basis of the saturation time at point 4 was 0.0869 lb. ethylene per lb. silica gel as compared to 0.090 interpolated from Figure 6 for 261 ppm ethylene in oxygen.

Hsu

McKinley

A. C. T. Hsu was associate professor of chemical engineering at Alabama Polytechnic Institute before joining Air Products three years ago. He now supervises the company's low temperature adsorption program. Hsu, a PhD from the University of Pennsylvania, has published work in the mass transfer field, as well as in low temperature techniques. C. McKinley, director of research and development at Air Products, is well known for his contributions to low temperature processing.

The empirical equation:

$$\frac{N_1 m}{N_1} + \frac{N_2 m}{N_2} = 1$$

suggested by Lewis and co-workers (7) has utility in estimating the effect of one adsorbate upon another when a binary mixture is being adsorbed. N_1 is the capacity for component 1 in the pure state and $N_1 m$ the capacity at the same concentration but in the mixture. The subscript 2 refers to the second component.

Experimentally, we have found that the gel capacity at point 4 for ethylene has been only slightly reduced by the presence of ethane in the carrier stream. On the other hand, the presence of ethylene in the carrier stream has suppressed the capacity of the gel for ethane from 0.004 lb./lb. to only about 5% of this value.

Displacement of ethane

Experiments were carried out in which silica gel was exposed to an ethane bearing stream until it was saturated; flow of this ethane bearing stream was terminated; and an ethylene bearing stream was sent through the gel saturated with ethane. Figure 8 shows an idealized monitoring record for such a run. The gel was first saturated with a mixture containing 165 ppm ethane in oxygen. The ethane-oxygen stream was then replaced with a mixture containing 156 ppm ethylene in oxygen, and the run continued until the ethylene saturation capacity was reached. The run was then stopped and the silica gel column was warmed up slowly to effect gradual desorption. Gas samples were taken at three points, as indicated in Figure 8, and analyzed chromatographically for their ethane and ethylene contents.

The carbon dioxide analyzer record indicated that in the first phase of adsorption, ethane broke through the column and reached the influent concentration in the usual fashion. After switching to ethylene-oxygen mixture, the ethane adsorbed on silica gel was continuously desorbed until its displacement by ethylene was essentially complete. The amount of ethane taken up by silica gel and the amount desorbed at the end of the run were found by material balance to be in satisfactory agreement. The exhaustive displacement of ethane by ethylene was also supported by the chromatographic analyses of the gas samples representing the adsorbed phase at the end of the run.

The ethane concentration at all three points was zero in the desorbed gas. The ethylene, which had entered at a concentration of 156 ppm, was substantially concentrated to 2000 ppm at point 1 and 10,000 ppm at point 2.

The adsorption-desorption-displacement mechanism in a working adsorber is very complex when handling a multi-component mixture, especially since there usually exist surges in concentration of these components in process streams. The striking ability of strongly adsorbed material to displace less strongly held components must be fully appreciated. Throughout an adsorbent bed, variable concentrations of adsorbates may exist. If the adsorbent possesses sufficient total capacity, this chromatographic effect may take place without resulting in undesired breakthrough of any of the components. The realistic understanding of working adsorbers should pave the way for safer and more efficient adsorbing units in cryogenic and other applications.

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Correction

In the article "Imprinted-Sector Rupture Discs" by William Weatherford, Jr., published in the December '59 *CEP*, pp. 42-44, the author's company affiliation was given as Southwest Research Institute. While this is true, the work described in the article was actually done entirely at the Mellon Institute, Pittsburgh, Pa.

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U.S.I. CHEMICAL NEWS

Feb. ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1960

Latest Statistics On Chemical Industry Given in New Facts Book

The 1960-61 edition of the Chemical Industry Facts Book, published recently by the Manufacturing Chemists' Association, presents a great deal of valuable data on the history, growth, contributions and current position of the industry. The book indicates that by mid-1959, in terms of assets, the chemical industry was fourth in size among all U. S. industries.

Eleven of 20 chapters in the new volume cover history, distinctive characteristics, products, position in the economy, contributions to the economy, future prospects, raw materials, workers, plants, finances, research and development. Nine more chapters discuss chemistry's contributions to food, agriculture, clothing, shelter, health, transportation and communications, defense, nuclear energy and space exploration.

New Fabrication Techniques Make Commercial Titanium-Clad Vessels a Reality

New bonding and welding methods have made it possible to construct a 4-foot diameter, 12-foot high, titanium-clad steel pressure vessel for processing highly corrosive chemicals at elevated pressures and temperatures. The vessel has been proved out through almost a year of service. As a result, titanium cladding is indicated as a cost-cutting measure in the manufacture of corrosion-resistant equipment for the Chemical Process Industries.

To avoid the problems of titanium contamination and brittle welds inherent in the direct joining of titanium and steel, an unidentified metallic powder is placed between the titanium-cladding sheet and the steel backing plate. By applying heat to liquefy the powder, and vacuum to insure a good seal, the cladding is bonded to the backing plate without direct contact between the two metals.

The clad plates are then welded to each other by another special process. Here, steel is joined to steel with a conventional weld. Then a silver inlay is laid along the joint on the titanium side, and covered with a fillet-welded titanium strap. This process eliminates contact between steel and titanium at the joint, and gives the vessel an all-titanium inner surface.

Butyl Acetate Data Sheet Now Available from U.S.I.

Specifications, properties, shipping data and applications for normal butyl acetate are given in a new data sheet just released by U.S.I. This material is the most widely used medium-boiling nitrocellulose solvent. It also finds application in the manufacture of cements, coated papers, lacquers, leather finishes, linoleum, textile sizing, thinners and a host of other products.

The data sheet can be obtained from U.S.I. sales offices or from the New York office at 99 Park Avenue.

New U.S.I. Technique Improves Optical Properties of Blown Polyethylene Tubing

Annealing Chamber Increases Light Transmittance, Reduces Haze

The U.S.I. Polymer Service Laboratory has developed an annealing chamber or "chimney" technique which results in significant improvement in clarity and gloss of blown polyethylene tubing, with practically no sacrifice of physical strength. The method involves installation of a chamber which encloses the blown tubing between extruder die and air ring.

Unit is easy to install

The chimney may be made of wood, glass or insulated metal. It should be constructed in two sections or hinged to permit installation during extrusion . . . thus eliminating need for rupturing the "bubble" when threading film through the annealing chamber.

Height of chimney is a critical factor. Optimum results are usually obtained with a 6 to 12" chimney height. While ratio of chimney diameter to die diameter is not critical, it should be held between 2:1 and 3:1. For example: a 3" die would require a 6 to 9" diameter chimney.

An evaluation of PETROTHENE P-200-25 resin using this technique revealed:

Optical Property	*No Chimney*	*8" Chimney*
Transmittance	30%	70%
Gloss	7%	11%
Haze	11%	4%

No significant change was noted in impact strength. Elmendorf tear tests showed that a directional strength balance was brought about by adding the chimney. Tear values increased in the transverse direction and decreased in the machine direction. Yield, break and elongation were essentially unchanged.

MORE

First Nonconjugated Polyacetylenes Synthesized By New, Low-Cost Process

Good yields of large carbocyclic compounds containing nonconjugated triple bonds have been achieved via a new process claimed to be simple and economical. The resulting compounds are being investigated by the rocket field as high energy binders and plasticizers for solid propellants and as intermediates for solid boron fuels. Other applications as intermediates are indicated by the presence of regularly spaced triple bonds in the new compounds.

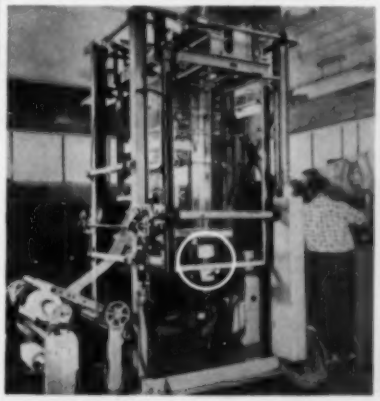
A mixture of mono- and disodium acetylides —made from metallic sodium and acetylene— are alkylated with α,ω-dihalides to yield linear and cyclic polyynes:

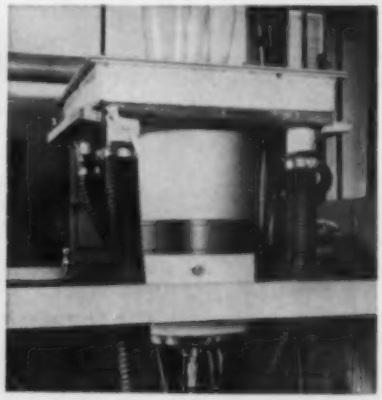
$$X(CH_2)_nX + \begin{matrix} Na-C\equiv C-H \\ Na-C\equiv C-Na \end{matrix} \longrightarrow$$

$$H-C\equiv C[(CH_2)_nC\equiv C]_xH + (CH_2)_n \begin{matrix} -C\equiv C- \\ -C\equiv C- \end{matrix} (CH_2)_n$$

In the reaction, the monosodium acetylide performs the function of chain stopper to control the formation of high molecular weight polyynes. Hydrogen-terminated polyynes are assured by the presence of excess sodium acetylides.

Highest yields are obtained by reacting dibromides at the boiling point of ammonia (−33.4°C), or dichlorides at elevated temperatures under autogenous ammonia pressures.





Polyethylene tubing has improved clarity and gloss when produced with new U.S.I. annealing chamber technique. Close-up view at right shows "chimney" between extruder and air ring.

Feb. ★ **U.S.I. CHEMICAL NEWS** ★ 1960

CONTINUED

Poly-ethylene

Work on this new technique is continuing at the U.S.I. Polymer Service Laboratory, where your inquiries are always welcomed. If you have special problems, U.S.I. engineers will gladly offer their assistance. You are also invited to write for a Technical Data Sheet describing the new process.

Anhydrous Alcohol-Freon Blend Developed to Clean Printed Circuit Boards

To clean printed circuit boards rapidly, safely and easily during production, a special solvent formulation has been developed which is claimed nonflammable, nonexplosive and low in toxicity. It is made up of a "Freon" solvent and a specially denatured anhydrous alcohol with an initial boiling point of 43°C.

The blend is said to clean oil, grease, excess rosin flux, fingerprints and other dirt from the boards after soldering and other assembly operations are finished. It can be used with semi-automatic cleaning equipment or in simple hand-dip baths. Reports indicate that it does an effective job without damage to circuit components, laminating cement, or most color coding and labeling on circuit parts.

Since the formulation is a blend of solvents, fractionation of the mixture will occur due to a higher evaporation rate for the lower boiling Freon component. Therefore, with continuous, automatic cleaning in a system which recovers or reclaims solvent vapors, the composition of the mixture must be checked from time to time.

For small-scale cleaning in a static bath, two-minute immersion of the board, with slight agitation, is said to be generally adequate for satisfactory cleaning. Four-minute immersion, with slight agitation, was the maximum time required to remove any type of soldering flux during test operations.

Molded Polyethylene Liner In Steel Pail Available For Chemical Shipments

A seamless, blown-in-one-piece polyethylene liner for a steel pail has been developed as another advance in solving the problem of safe and economical packaging of corrosive liquids. This container is expected to find wide application in packaging and shipping products such as acids and alkalies, food concentrates, photographic chemicals, electrochemicals and insecticides.

The result of over two years of research and development work, the package has been approved by the Bureau of Explosives to carry certain corrosive, poisonous and flammable liquids under ICC-37P specification. It has been successfully subjected to vibration and drop tests from 0°F. to 125°F.—tests more exhaustive than those required by ICC and Federal specifications.

The liner is blow-molded of polyethylene in the same manner as a "squeeze bottle," and is then attached to the cover of the outer steel container at the pouring opening, before it is inserted in the container. Its one-piece construction is said to insure against leakage and product contamination.

(*Photo courtesy Jones & Laughlin Steel Corp.*)

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

New journal now being published on mathematical analysis and applications. Said to permit rapid publication of selected mathematical papers on classical analysis and applications in fields such as physics, chemistry, biology. **No. 1560**

Plastic laboratory equipment now available, from aprons to Y-connectors, covered in new catalog just issued. Plastics represented include polyethylene, styrene, teflon, nylon, polypropylene, acetates, acrylics, vinyls. **No. 1561**

Rigid, fire-resistant polyurethane foams can now be prepared from new alkyd resin system which used trichlorofluoromethane as foaming agent. Said to be of interest for cores in sandwich construction, insulation applications. **No. 1562**

Current projects of American Standards Assn. are described in booklet released recently. Covers 425 projects, categories and gives scope of each, provides index and lists sponsors. Whys and hows on standards outlined. **No. 1563**

Method of analysis of sodium hydride, for contained sodium hydride and residual sodium, covered in technical data sheet now available. Describes apparatus, procedure, offers technical assistance. **No. 1564**

Russian-English atomic dictionary, second edition, can now be purchased. Over 23,000 Russian entries cover nuclear science and technology, physics (theoretical, atomic, molecular), physics of solids, crystallography, math. **No. 1565**

Flash points of more than 4,500 trade-name liquids are listed in new reference index now being sold. Data include manufacturers' names, principal uses of products, and sources of information given. **No. 1566**

Metal cleaning chemistry and techniques discussed in 28-page handbook now available. Includes electro-, barrel, ultrasonic and machine cleaning, plus tank cleaning, with suggestions for tank design, layout, detergents. **No. 1567**

Instrumentation literature now being abstracted by new service. Claims to cover all significant articles of interest to chemical, petroleum, food, steel and glass fields. Abstracts journals, papers, patents, books. **No. 1568**

High frequency induction furnace can now be obtained which can operate in pure hydrogen or oxygen atmosphere up to 5,000° F. Makes use of zirconia and/or thoria pure oxide refractories, as susceptor or heating element. **No. 1569**

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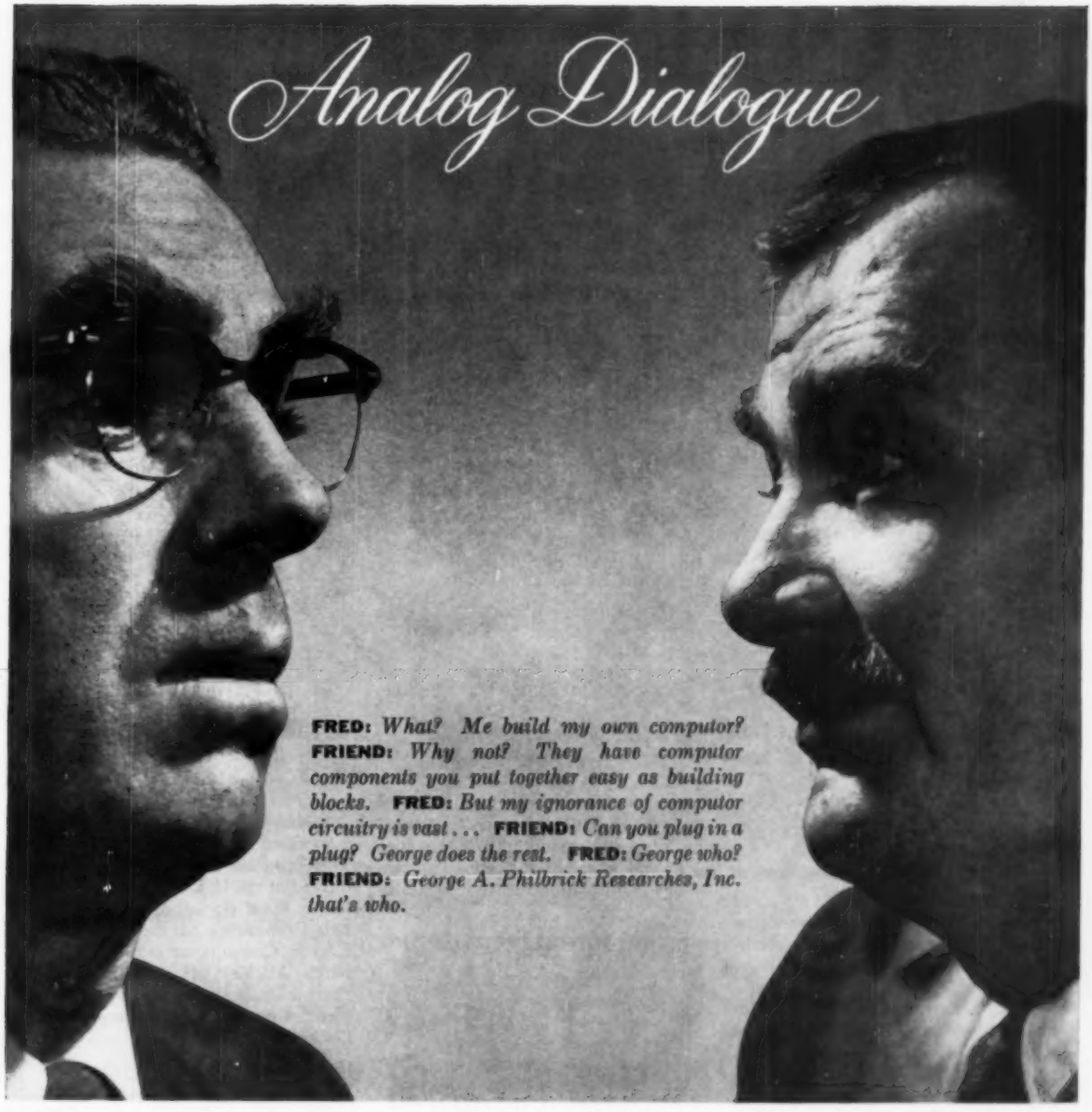
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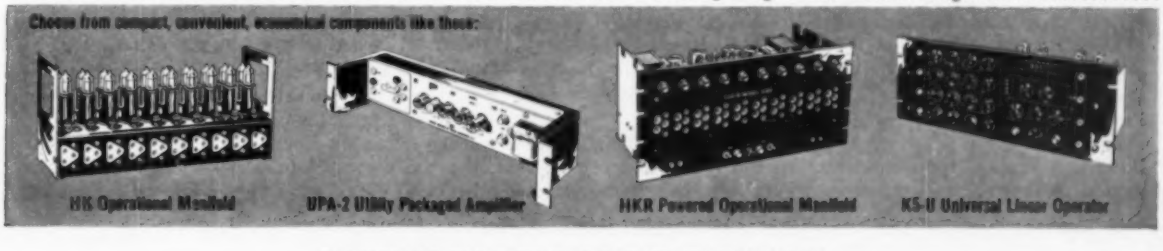
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CEP

COMPUTER PROGRAM abstracts

Based on the interest which has been expressed to date, the Machine Computation Committee is proceeding to have the following manuals prepared, reviewed, and published.

Abstract No.	Program	Computer	Contributor
002	Piping Flexibility	Univac I	duPont
017	Humble Plate to Plate	IBM 705	Humble
028	Multiple Regression Analysis	IBM 650	Shell
032	Minimum Reflux for Distillation	Datatron 205	California Research Corporation

The Machine Computation Committee of the A.I.Ch.E. is interested in receiving program abstracts. Once again the Committee wishes to emphasize the three rules for participation in the interchange program:

1) Abstracts submitted for publication must follow the form published in *CEP* (January, 1959) and in the *Guide*.

2) Abstracts must be sent to the Machine Computation Committee c/o A.I.Ch.E.

3) All questions relating to published abstracts must be sent to the Committee c/o A.I.Ch.E. in New York.

Electric Log Interpretation (039)

Howard A. Slack and Melvin A. Rosenfeld
The Pure Oil Company, Research Center, Crystal Lake, Illinois

Description: This program calculates two quantities—shaliness and saturation ratio from the data obtained from conventional electric logs of shaly sands. Shaliness is a measure of the amount of disseminated clay material in the formation. It is calculated from the recorded Self Potential, the interstitial water and mud filtrate resistivities, and the formation temperature. The saturation ratio is the ratio of mud filtrate saturation in the invaded zone to the interstitial water saturation in the non-invaded zone. It is calculated from the Self Potential, the shaliness and the true resistivities of the formation and invaded zone.

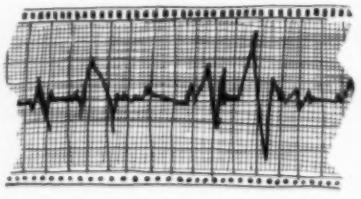
The equations used in making these calculations are after L. deWitte as published in his paper "A Study of Electric Log Interpretation Methods in Shaly Formations" *Journal of Petroleum Technology*, Vol. 204, 1955.

Computer: IBM 650.

Program language: Machine Language.

Running time: Approximately 1 second per case.

Comments: Two answers—an upper and a lower limit—are given for saturation ratio corresponding to two values of formation resistivity ratio. The two values of formation resistivity ratio in



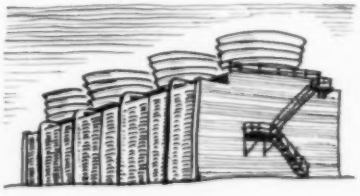
turn correspond to two assumed depths of invasion by mud filtrate.

Availability: A program manual has been written and can be made available for publication should sufficient interest develop.

Solution of counterflow water cooling tower (040)

N. H. Van Wie, J. E. Park, and J. T. Hardy
Union Carbide Nuclear Company, Operations Analysis Division, Oak Ridge, Tenn.

Description: This program calculates the return water temperature to the process heat exchangers and other performance conditions with a given characteristic of the active "fill" of the cooling tower, a given plant energy load, and given water circulation rate and air throughput and ambient conditions. Thus, a stated relationship between the unit volume coefficient or characteristic of a given tower fill and height and the liquid to gas ratio will permit numerical integration of Merkel's formula to determine the process cooling water characteristics attainable. Where the tower has ex-



cessive cooling capacity, the program calculates the amount of hot water that should be by-passed to maintain a specified supply water temperature. This program is based on work performed at the Oak Ridge Gaseous Diffusion Plant operated by Union Carbide Corporation for the U. S. Atomic Energy Commission.

REF: Mickley, H. S., "Design of Forced Draft Air Conditioning Equipment", *Chemical Engineering Progress*, December 1949.

Computer: IBM 704.

Program language: Fortran.

Running time: Three to four cases per minute.

Comments: Needed thermodynamic properties of air and water vapor are based on correlations rather than being tabled. Iterative adjustment of water temperatures continues until check within 0.05°F. is obtained, with the exception that tolerance of higher (0.75°F.) discrepancy in return water temperature is allowed in deciding whether tower by-pass is required.

Availability: The intracompany memorandum describing this operational program is available and a complete manual will be prepared if there is deemed to be sufficient interest.

continued on page 92

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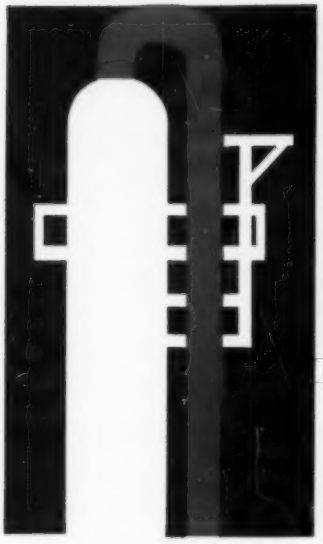

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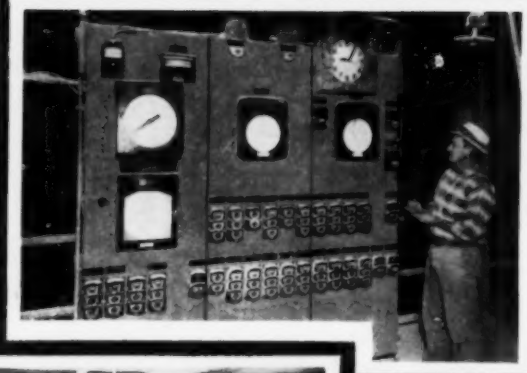
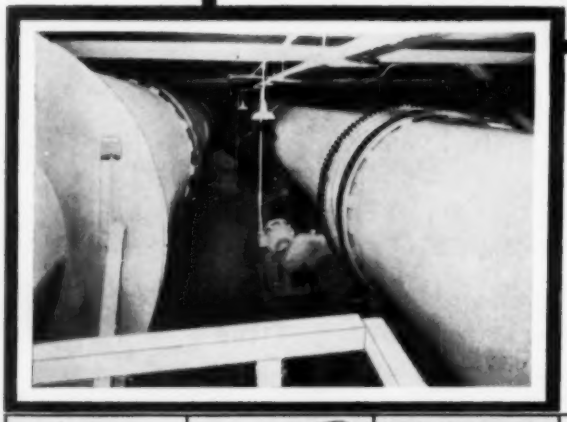


INSTRUMENT PANEL—"Nerve center of a large Renneburg designed and equipped chemical plant. Includes furnace pyrometer; temperature indicating, recording and controlling potentiometers; load indicating ammeter; and start-stop push button stations with signal lights for each machine. Audio-howlers warn operators of possible processing difficulties.



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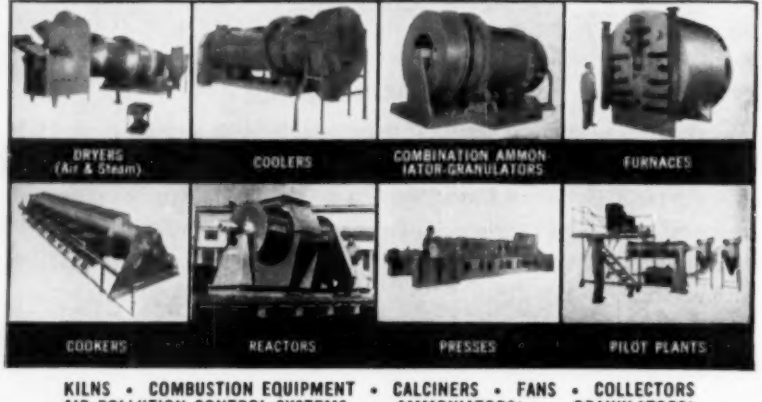

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Computer abstracts

from page 90

Operational Characteristics of Isothermal Tubular Flow Reactors (041)

Richard C. Bailie and Liang-tseng Fan
Department of Chemical Engineering
Engineering Experiment Station
Kansas State University of Agriculture and Applied Science
Manhattan, Kansas

Description: A material balance of the tubular flow reactors (including packed bed and fluidized bed reactors) operated under isothermal steady state conditions yields the following differential equation when the concentration in the radial direction is assumed to be uniform.

Ref. Yagi, S. and Miyanchi, T., *Chem. Eng. (Japan)*, *19*, 507, (1955)

$$\frac{d^2\gamma}{d\eta^2} - 2\bar{U}\frac{d\gamma}{d\eta} - \bar{U}R_n\gamma^n = 0$$

where

$$\gamma = \frac{C-C_e}{C_o-C_e}, \eta = \frac{1}{L}, \bar{U} = \frac{\bar{u}L}{2E}$$

$$R_n = \frac{^2k_nL}{\bar{u}}(C_o-C_e)_n$$

C = concentration of reactant
C_e = equilibrium concentration of reactant
C_o = concentration of reactant coming into reactor
l = distance measured along the flow direction from the inlet of reactor
L = reactor length
$\bar{u}$ = mean linear velocity of reacting mixture
E = longitudinal mixing coefficient (for longitudinal eddy diffusivity)
n = order of reaction (including fractional order)
k_n = rate constant of n-th order reaction

The known boundary conditions are as follows:

$$\text{at } \eta = 0, \frac{d\gamma}{d\eta} = 2\bar{U}\,(\gamma_{\eta\to 0} - 1)$$

$$\text{at } \eta = 1, \frac{d\gamma}{d\eta} = 0$$

This program solves the differential equation given by method of finite differences and can use any number of pivotal points (maximum 500) depending upon accuracy desired. The concentration profile throughout the reactor is obtained from the concen-

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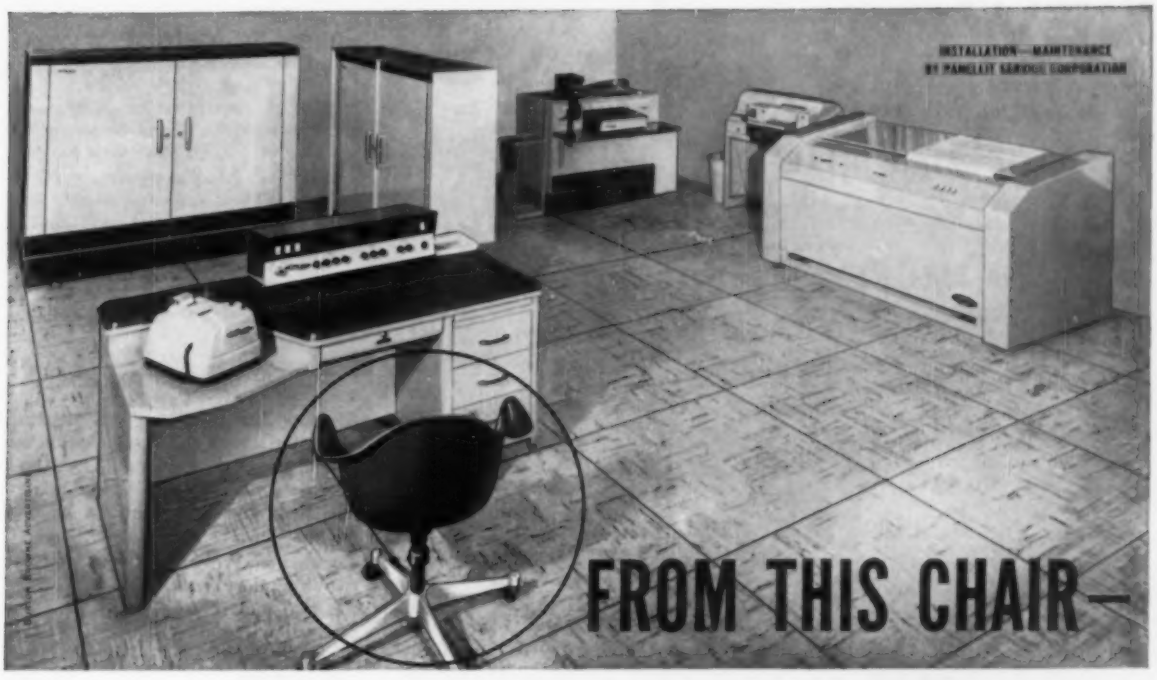

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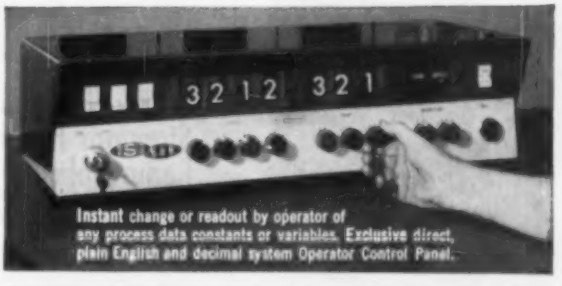
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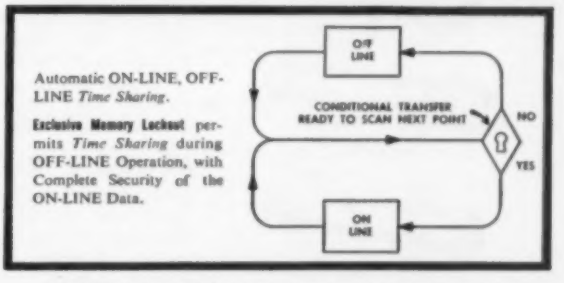
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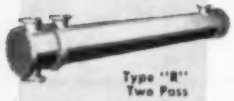

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For more information, turn to Data Service card, circle No. 33

Computer abstracts

from page 92

tration of each pivotal point, and, consequently, the degree of conversion of the reactant for the given reacting conditions from the known degree of backmixing and the reaction rate constant can be obtained at any point in the reactor.

Computer: Basic IBM 650 with alphabetic attachment and 2,000 word storage, floating point and index registers.

Program Language: Program prepared with SOAP routine.

Running Time: Running time depends upon the accuracy desired. For example, it is approximately three minutes for 50 increments, and matching of boundary conditions to four decimal places.

Comments: Program checks that the two boundary conditions existing at the two ends of the reactors can be satisfied within the accuracy of eight decimal places of the dimensionless concentration.

Availability: A program manual can be made available for publication should sufficient interest develop. Kansas State University Engineering Experimental Station Bulletin covering this program will also be prepared.

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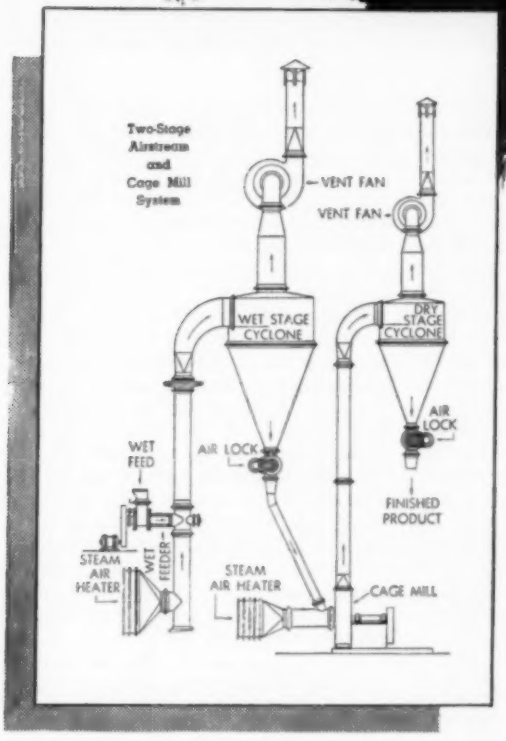

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equipment feature

J. W. Ranftl, *General Electric Co.*

Irradiation techniques in chemical processing

Practical, economic irradiation facilities are now within the reach of even the smaller chemical producing companies.

Crosslinking produced by the irradiation of polyethylene raises the melting point of the material and greatly extends the usefulness of certain products. The irradiation effect will also greatly increase the resistance of the polyethylene to chemical solvents and to environmental stress cracking. Grafting of certain polymers on other materials by means of radiation can give these materials new properties which extend their usefulness. As an example, radiation is useful in producing ion exchange membranes for water desalting cells. Such grafted materials can also be made to have improved adhesive properties.

If uniform radiation is to be given a product, the effective thickness that can be handled in a single layer will be less. For materials of lesser density, the penetration will be greater and, conversely, where the density of the material is higher, the depth of penetration will be reduced in inverse proportion. With many materials, it is possible to irradiate from two sides, either by turning the material over and passing it through the beam a second time, or by passing the material through two opposing beams of radiation. In that case, uniform radiation effect will be given to greater thicknesses than the total penetrating value for radiation of the given voltage.

Space requirements

Generally, the irradiation process is applied in the final steps of manufacture, rather than to raw material before fabrication. The machine is placed in a separate room or in a part of a building that is shielded by a heavy barrier wall from those areas occupied by plant personnel. The floor space required will depend upon the size of the irradiation machine installed and, to a large extent, on the particular material being handled and the space requirements for handling equipment such as reeling and unreeling devices, conveyors, and the like. The thickness of the shielding walls will add to the floor area, as will the space required for auxiliary components and operator's console outside the irradiation area. A total floor space of 500 to 1,000 square feet would be a practical amount to assign to the irradiation process. Requirements for the height of the installation will vary with the particular equipment, but will generally range from 15 to 30 feet. The total room height may be entirely in the irradiation chamber or may be divided by a barrier ceiling separating the irradiation chamber from the room above, which contains the main body of the machine.

Shielding

Shielding is necessary to protect personnel from radiation produced when the machine is turned on. When the machine is turned off, the area can be entered safely, since there is no residual radioactivity either from the machine or from its shielding under normal processing conditions. Shielding may be of many materials. Lead and heavy metals are excellent absorbers, but their cost is high. Concrete mixed with iron ore or heavy mineral aggregates is also efficient, but expensive. Poured concrete walls or solid concrete blocks laid into wall form are the most common shielding materials. Concrete 2½ feet thick is required for one million volt radiation, and 3½ feet for two million volts. These are typical values; exact thickness will depend on voltage and kilowattage of the machine, size of the room, and room geometry. Another method is to excavate for a radiation pit to use the natural shielding properties of the earth. Figure 1 shows a floor plan of one type of installation.

For operator access, a maze structure can give radiation shielding, and

continued on page 100

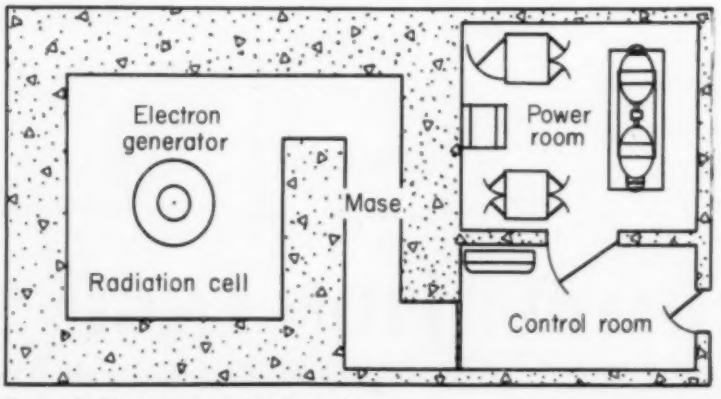

Figure 1. Electron generator floor plan.

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Length	Diameter
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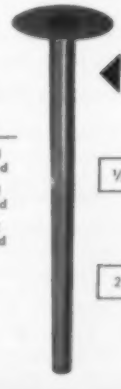
60"	6"-wide end 2"-narrow end
60"	8"-wide end 4"-narrow end



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A workman at Glidden dresses an 18-inch T. Shriver press with Eaton-Dikeman Filter Paper supplied by The Keeler Co., 1033 Bern Road, Wyomissing, Pa.

Eaton-Dikeman Filter Paper helps GLIDDEN paint an improved production picture

When The Glidden Company switched from cloth filters to Eaton-Dikeman Filter Paper in their Reading, Pa., Varnish plant, they gained two important advantages:

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For more information, turn to Data Service card, circle No. 107

Irradiation techniques

from page 96

affords easy entrance to the room without use of heavy doors. The operator's console is placed near the entrance to the irradiation room. Other electrical components are placed in an adjacent room. A mirror system will work well with a maze layout. A more versatile arrangement, however, is the use of an industrial television camera and monitor. A very direct view can be had by use of a window made of radiation-absorbing glass, or a liquid cell in the wall of the room.

Radiation dosage

The basic unit of radiation dosage is the rad. By definition, this is the absorption of 100 ergs of energy per gram of material. In more practical units, the delivery of 1,000,000 rads will require 1.26 watt-hours of electron energy absorbed per pound of material processed. To establish a dose level scale, we note that insect contamination in grain can be effectively combatted with 10,000 rad. Going up the scale, 100,000 rad will have a noticeably destructive effect on molds and bacteria. The more resistant bacteria will require 1,000,000 to 4,000,000 rad for complete destruction. Enzymes will require doses in the range of several million rad for inactivation. Some chemical effects will be promoted at 1,000,000 rad, or even lower doses. However, 1,000,000 rad or higher is a more common level for chemical reactions. Radiation effects are generally not threshold effects, so the greater doses produce proportionately more change in the material being processed.

Present day accelerators, such as the General Electric 2 MEV Resonant Transformer Electron Beam Generator, have large radiation outputs. The emergent electron beam of this machine has a power of 10 kilowatts. If the beam could be used at 100% efficiency, 8,000 pounds of material per hour could be processed at a level of 1,000,000 rad. The efficiency of absorption will seldom be 100%, but even at lower values, it can be seen that the processing capacity is substantial.

For most processes, the beam overtravel efficiency is about 90%. A combination of several efficiencies results in efficiencies of about 40 to 50% for single-side irradiation where a minimum uniform dosage is to be maintained. In two-sided irradiation, where product thickness and voltage are

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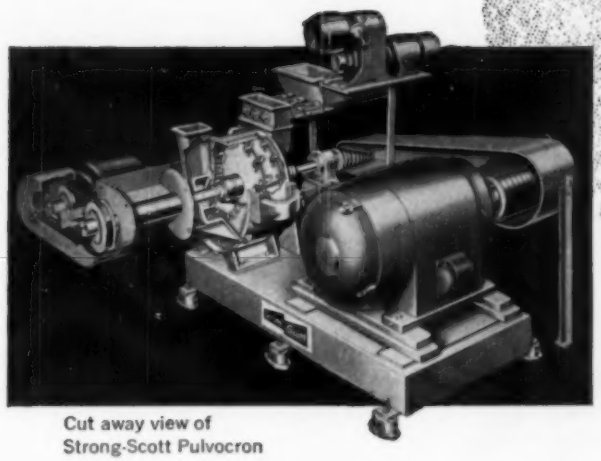

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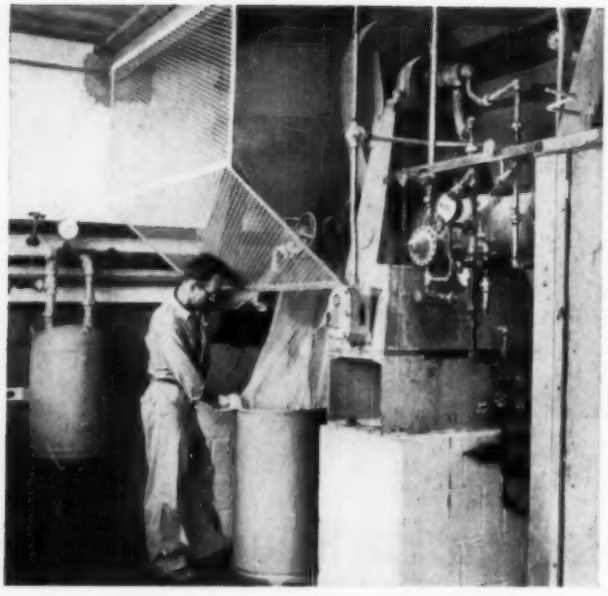

"ASSURES SUPERIOR DRYING OF HEAT SENSITIVE MATERIALS" says BENZOL PRODUCTS.

The Benzol Products Plant at New Brunswick, New Jersey does its final drying and blending of barbiturates and other heat sensitive materials in a Paul O. Abbé Rota-Cone Dryer.

"Since using your dryer," states a spokesman for the company, "we do not get any decomposition of the material. The tumbling action assures contact of the material with the heated surface. The vacuum removes the moisture-laden air. In consequence, we are able to dry at lower temperature and evenly."

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Other reported advantages of the Rota-Cone method of drying in comparison with the tray drying previously used by this company include: less exposure to dirt, more economical of space, 33% less labor. Temperature is automatically controlled from 30°C. to 90°C.

Type of products being dried in the Rota-Cone today are: pharmaceutical powders, plastic resins, chemicals in powdered, flake and granule form, textiles, and metal powders.

Why risk decomposition of heat-sensitive materials, dirt, and higher labor costs when you can avoid them by using a Paul O. Abbé Rota-Cone Dryer?

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PAUL O. ABBÉ

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For more information, turn to Data Service card, circle No. 39

Irradiation techniques

from page 98

properly matched, efficiency is from 50 to 75%. This increases to 90 to 100% for single-side irradiation of a flowing liquid or gaseous product where the reaction is a function of total absorbed power only, and is not dependent on uniformity within individual product elements.

Capital costs

As a general estimating value for a full-scale production process, radiation can be delivered to the product for about ½ to 1 cent per megarad-pound, including operating costs, amortization of machine and shielding, and return on investment. The minimum capital investment for production irradiation would total about $100,000, an amount which can often be reduced through lease of the equipment.

Over 200 long tons of sulfur a day and 50 million cubic feet of raw gas will be produced at the sulfur recovery and cycling plant now under construction for Tidewater Oil at Franklin County, Texas. One of the largest such plants in the country, the unit will, in addition to the sulfur, remove some 7500 barrels a day from the raw gas, over 1000 of propane and 550 of butane daily. Hydrogen sulfide removal from the raw gas is by the Girbotol process. Tidewater and Texaco each have 46 percent in the New Hope Field, Humble Oil owns 4 percent.

A new source of polyethylene glycol is now available, with Allied Chemicals' manufacturing facility now on stream at Orange, Texas. Offered are PEG 200, 300, 400, 600, 1000, and 1450, and in combination shipments with other glycols and ethanolamines.

Tetra potassium pyrophosphate, the latest to be added to Hooker Chemicals product line, is the principal product to be manufactured at the company's new plant in Jeffersonville, Indiana. Target date for operations to begin is mid-1960.

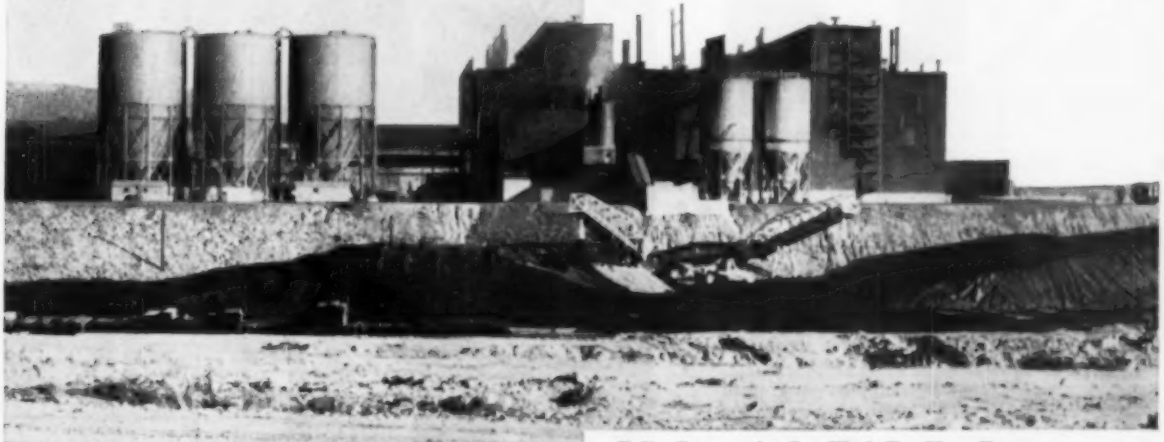
A $10 million oil company with main offices in Hongkong will concentrate on marketing in Southeast Asia and the Middle East. Incorporated under the joint ownership of Union Oil of California and Maruzen Oil of Japan, Unimar, Inc. will get products for the fully integrated operation from each company's refineries.

How Pneumatic Conveying Helps Make New Mining Process Economically Practical

Taconite processing is typical of the many varied, cost-saving applications for Fuller Pneumatic Conveying.

They're turning low assay iron ore into rich pellets on the Mesabi these days. Moving additives for pelletizing, Fuller plays a special role in this feat of engineering and production economy.

Fuller Pneumatic Conveying Systems are carrying fine anthracite screenings, soda ash, and bentonite from siding to storage to processing—with speed, safety, sanitation, and efficiency. With few moving parts to wear out and powered by inexpensive low-pressure air, Fuller Pneumatic Conveying Systems speed dry bulk materials *anywhere that a pipeline can be run:* under ground, up through floors, around corners . . . for far greater distances and at substantially lower cost than possible with mechanical conveyors.



Four Fuller Pneumatic Systems can speed more than 307 long *tons* of additives through this huge Taconite Pelletizing Plant in a single day.

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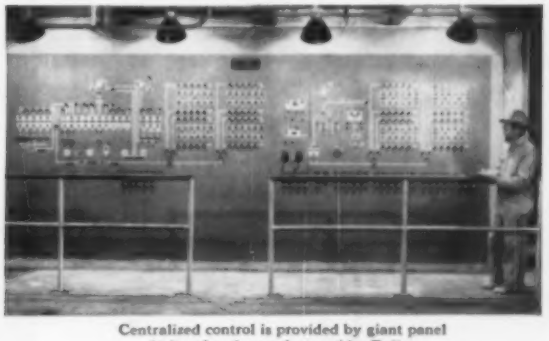

Centralized control is provided by giant panel designed and manufactured by Fuller.

See Chemical Engineering Catalog for details and specifications.

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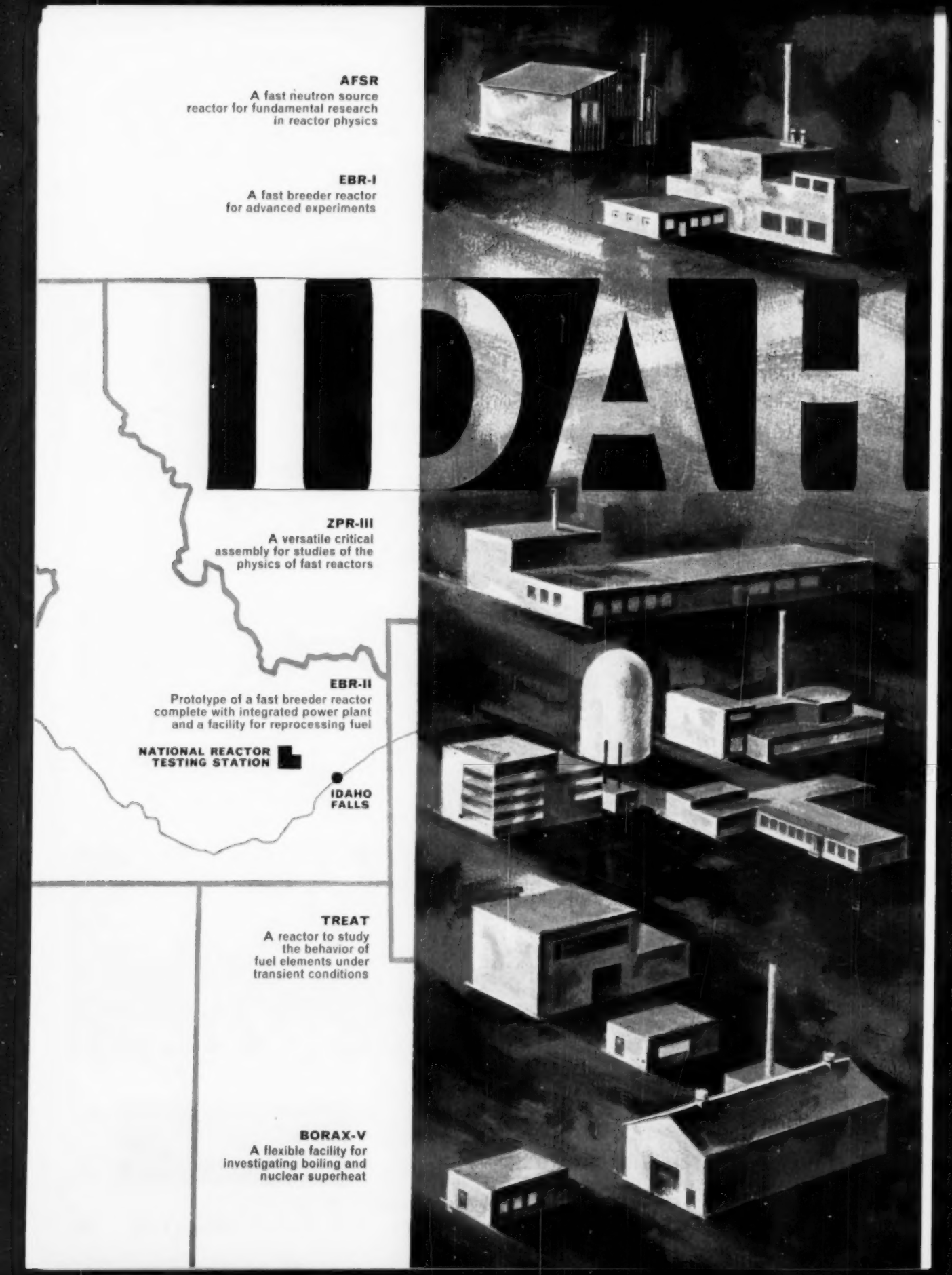
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IDAHO FALLS
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BORAX-V
A flexible facility for investigating boiling and nuclear superheat

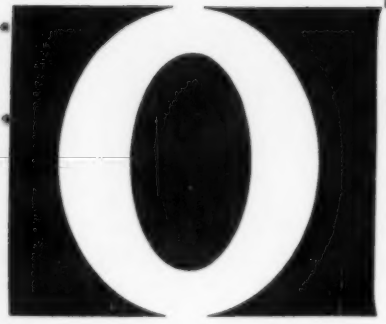
The Idaho Division of Argonne National Laboratory has a distinguished record of contribution toward realization of our nation's objective of economic nuclear power. Included in the proud chronicle of its historical accomplishments toward peaceful applications of the atom are:

The first generation of useful amounts of electricity from the atom, (EBR-I, 1951);

The first demonstration of breeding of nuclear fuel, proving the feasibility of producing in a reactor more fuel than is consumed during operation, (EBR-I, 1953);

The first boiling reactor, verifying the practicability of using nuclear-created steam directly in a turbogenerator system to produce electricity, (BORAX-I, 1953);

The first use of atomic power to light a town (Arco, Idaho, by BORAX-III, June, 1955).



Concepts today that are programming America's future

Ambitious plans are still in the making at Argonne's Idaho Division. This unique proving ground, operated in close cooperation with the other divisions of Argonne National Laboratory, provides an unsurpassed variety of reactors and associated research programs to challenge the creative scientist and engineer.

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PLEASE WRITE TO:
Meyer Novick, Director
Idaho Division
Argonne National Laboratory
P. O. Box 2528-IA6
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P. O. Box 299-IA6
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industrial news

From the sands of Athabasca

Four-company combine mounts pilot-plant attack on 40 billion barrel hydrocarbon reserve, said to be world's largest.

Figure 1. Mining wheel in operation at Mildred Lake.

A PARTNERSHIP of four American and Canadian oil companies are making an all-out try at development of a method for extraction of hydrocarbons from the immense oil sands reserve along the banks of the Athabasca River in northern Alberta, Canada. Companies involved in the venture are Imperial Oil Limited, Cities Service Athabasca, subsidiary of Cities Service Co., Richfield Oil, and Royalite Oil. The first three hold 30% interests, Royalite 10%.

The Athabasca sands, estimated to contain some 40 billion barrels of hydrocarbons (about equal to total proved resources of North America), average about 10% hydrocarbons by weight. The hydrocarbons are approximately 7.5 A.P.I. gravity, and are solid at atmospheric temperature. About 50% of the hydrocarbon content boils below 1,000°F. Sulfur content is roughly 5%, vanadium runs about 200 ppm.

Mining technique—economic key

Paramount factor in economic exploitation of the long-known Athabasca hydrocarbon deposit is the cost of mining the tar sands. Typical sands range from 150 to 200 feet in thickness, overburden varies from 25 to 100 feet.

Pilot-plant operations, under way since August, 1959, are believed to have demonstrated a workable mining technique. A German-designed and built "mining wheel", based on a model used in Germany for commercial exploitation of brown coal does the trick. The diesel-electric experimental wheel being used at the Mildred Lake site can handle 9,600 cubic yards of material per day. The extraction equipment has been designed as a portable, self-propelled unit, capable of operating in the field along with the mining equipment.

Process

The bituminous sands are delivered by a belt conveyor from the bucket wheel to the extraction unit. Rocks and foreign material are separated. The basic extraction process employs a diluent—produced from the bitumin itself—to reduce the viscosity and specific gravity of the bitumin. Water is then added to precipitate the sand, freeing the diluted bitumin for subsequent processing. The oily mixture of diluent and bitumin is decanted from the water which is recycled to extraction.

The diluent recovery unit at Mildred Lake is designed to process 3,000 barrel per day of a mixture of 67% diluent and 33% bitumin by volume. Diluent recovery is effected by flashing at high temperature and ambient pressure.

Diluent is returned to the extraction unit, while the virgin bitumin is split into two streams, one to storage for use as fuel, and another which goes into a thermal cracking unit ("visbreaking").

Because of the high sulfur content (5%), it is considered probable that hydrogenation will turn out to be the only practical method of converting the extracted bitumin to an acceptable low-sulfur crude—intensive experimental work in this direction is said to be under way.

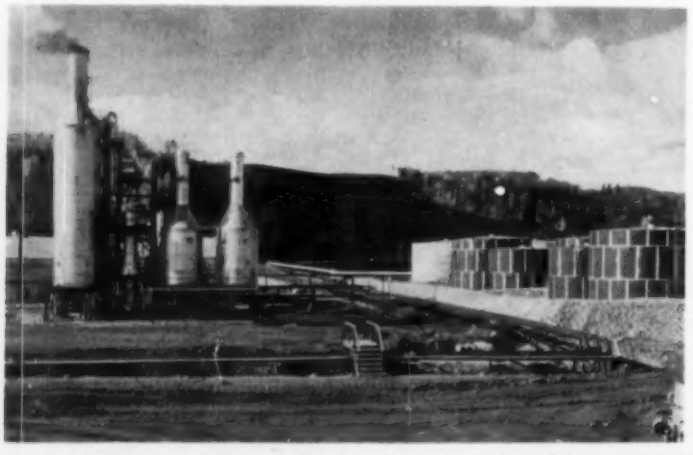

Figure 2. Refining and storage equipment at the Mildred Lake pilot plant.

Computer monitors power plant

Transistor unit operates six months with 99-75/100% reliability. Dependability of solid-state design proved in trial run.

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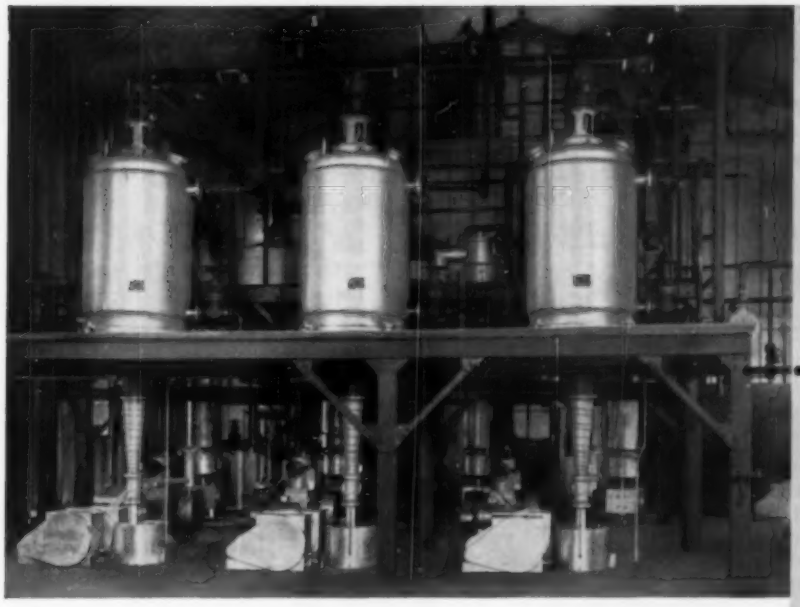
continued on page 106



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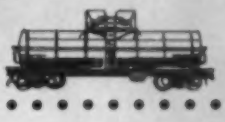

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For more information, turn to Data Service card, circle No. 118

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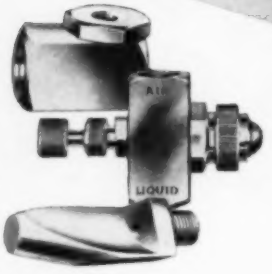

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For more information, turn to Data Service card, circle No. 2

Computer monitors

from page 104

Daystrom, Inc. Daystrom, which makes the equipment, bases its claim on an installation which monitored an electric power station, virtually without stopping, during a six month test period.

Data from the Sterlington, La. station of Louisiana Power and Light Co., indicate that the complex data logging and computer equipment operated at 99.75% efficiency for the six month, twenty-four-hour-a-day, seven-day-a-week trial run. The computer automatically monitored 350 points involving temperatures, pressures, and flows; identified, located, and recorded process deviations; and instantaneously recorded any process variable plant operators desired.

The key to the high reliability, according to Daystrom, are the new design techniques used in the general-purpose digital computer. All electron tubes and moving parts have been eliminated in this unit. Instead, only solid state devices such as transistors and diodes are used.

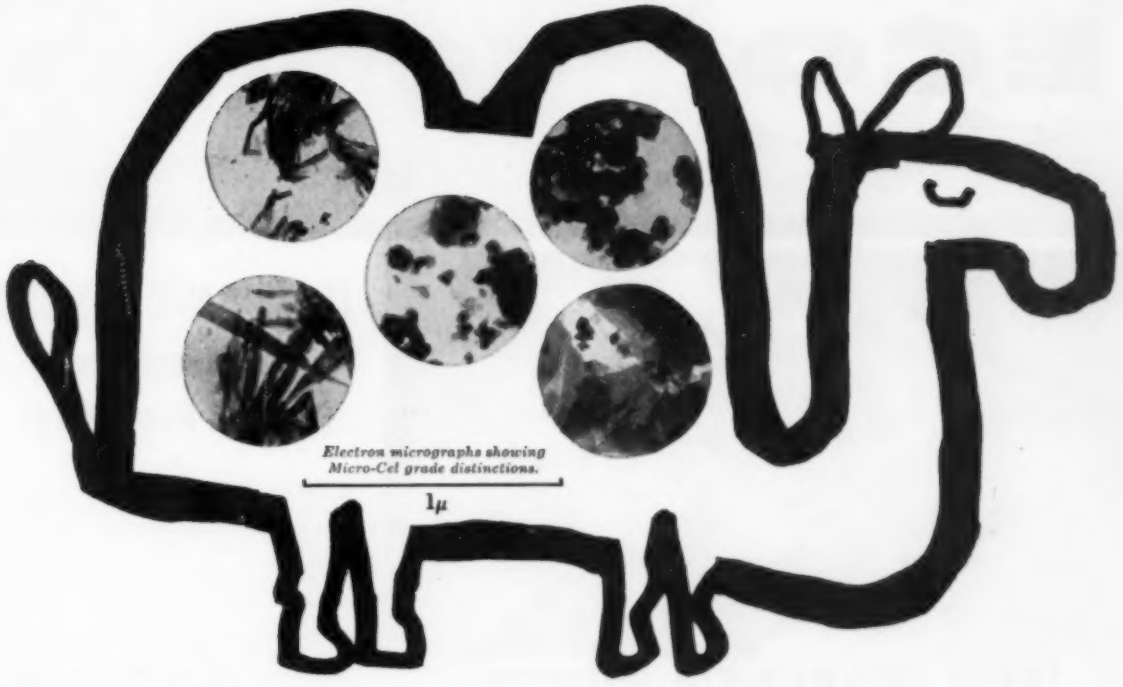
Louisiana Power and Light is installing a Daystrom digital computer control system for fully automatic control of its new power station at Little Gypsy, La. Plans are for the equipment to automatically start, operate, and shut down the generating station based upon information obtained by monitoring 1226 process check points.

Maleic anhydride production is shaping up at Heyden Newport, with a 24 million pounds a year capacity unit at Fords, New Jersey, now under construction. Anticipated on stream date for the new plant is late 1960.

A 20 million pound a year maleic installation has also been started at the Richmond refinery of Standard Oil of California, for Oronite Chemical, a Standard subsidiary. Completion is due in mid-1960.

Du Pont's paint plant, making lacquers, enamels, varnishes and thinners, for the Belgian market, expects to be in full production by March, 1960. Other European countries, it is expected, will be supplied later in the year.

Reichhold Chemicals has sold the Lindsay, Ontario, plant of its recently acquired Varcum Chemical Division to Reichhold Chemicals, Ltd. of Canada. The plant is one of the largest producers of phenolic molding compounds in Canada.



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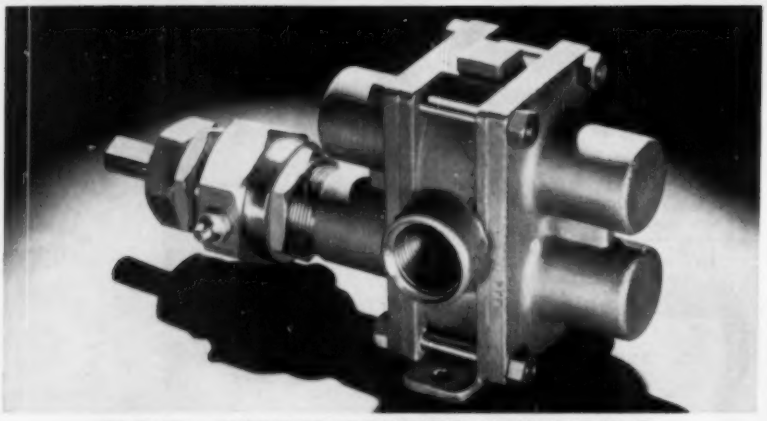
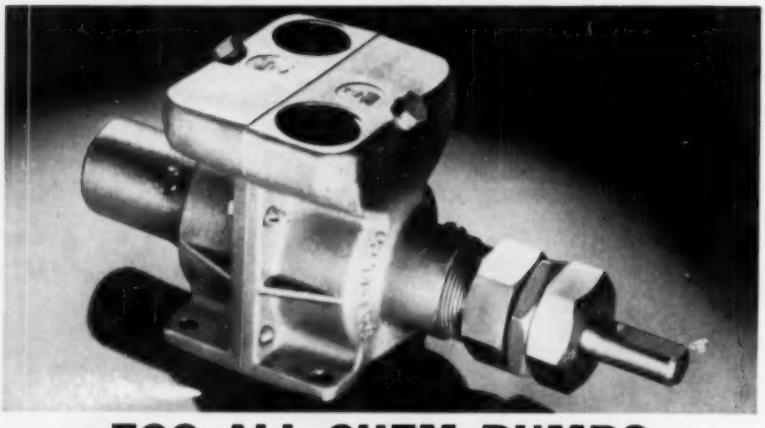


ECO GEARCHEM PUMPS



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ROTARY: If you want linear, non-segmented, non-foaming flows, ideal for shear-sensitive emulsions and safe for auto-detonating fluids—select the self-priming Eco ALL-CHEM Rotary displacement pump with twin opposed oscillating impellers. Designed for severe corrosive service. For reduced viscosities and temperatures to 250° F. Capacities to 10 gpm. Pressures to 100 psi. Suitable for metering in conjunction with Rotometers.

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Air Distributor (p. 10). "Thermal-Aire" plug units are inserted directly into furnace, oven, or kiln, eliminate need for duct work. Data from Garden City Fan & Blower. **Circle 79.**

Blenders, rotary (p. 138). Nine standard models with capacities to 900 cu. ft. Bulletin 080B from Sturtevant Mill. **Circle 58.**

Calciners, continuous, indirect-heat (p. IFC). Specially designed for high-temperature processing in neutral, oxidizing, or reducing atmospheres. Bulletin 118 from C. O. Bartlett & Snow. **Circle 56.**

Centrifugals, solid-bowl (p. 85). In seven sizes, each capable of twenty-five variations in design. Data from Bird Machine. **Circle 106.**

Comparators (p. 128). Handbook from W. A. Taylor has 101 pages of technical data on theory and application of pH control. **Circle 78.**

Compressors (p. 34). Technical engineering data from Ingersoll-Rand. **Circle 114.**

Computers, analog (p. 89). Complete line of electronic computers and com-

continued on page 110

MATERIALS

Alcohol-Freon Solvent Formulation (p. 87-88). Data from U. S. Industrial Chemicals. **Circle 126-5.**

Butyl Acetate (p. 87-88). Data Sheet from U. S. Industrial Chemicals gives specifications, properties, shipping data, applications. **Circle 126-4.**

Carbon, activated, granular (p. 14). Booklet from Pittsburgh Coke & Chemical describes liquid, vapor phase applications. **Circle 74.**

Coatings, protective, high-temperature (p. 158). Technical data from Midland Industrial Finishes on "Sicon" heat-resistant finishes. **Circle 10.**

Coatings, protective, inorganic (p. 120). Data from Carboline on "Carbo Zinc 11," new zinc-filled inorganic coating material for all-weather application and service. **Circle 128.**

Desiccants (p. 107). Johns-Manville offers technical data, samples of new "Micro-Cel" line of synthetic calcium silicates. **Circle 54.**

Ethylene Oxide (p. 18). Bulletin from Matheson gives specifications and physical constants. **Circle 36-2.**

Gases, compressed (p. 18). Prices

continued on page 110

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Computers, engineering (p. 91). Data from IBM on its new 1620, a desk-size engineering computer. **Circle 147.**

Computers, general purpose (p. 93). Technical data from Information Systems on the Panellit ISI Process Information & Computer System. **Circle 27.**

Condenser, evaporative (p. 11). Uses no external source of water. Data from Graham Mfg. on the "Aquamizer." **Circle 73.**

Conductivity Cells (p. 145). Catalog from Industrial Instruments gives details of many types. **Circle 35.**

Contactor, rotating-disc (p. 123). Bulletin T-1159 from General American Transportation. **Circle 57.**

Control, level (p. 130). With external adjustment for proportional band and liquid level height. Data from Fisher Governor. **Circle 17.**

Control Sytem, visual (p. 157). Booklet BE-20 from Graphic Systems. **Circle 80.**

Controllers, program (p. 12). Infinitely modulates heater power, coordinates time- and temperature-control for even most unstable systems. Bulletins JSB and JG from West Instrument. **Circle 15.**

Conveyors, pneumatic (p. 127). Bulletin 143-B from Spencer Turbine describes stationary and portable systems, gives typical applications. **Circle 38.**

Conveyors, pneumatic (p. 101). Technical data from Fuller. **Circle 23.**

Detector, voids (p. 28). Locates skips and "holidays" in protective coatings. Bulletin and technical data from Tinker & Rasor. **Circle 32.**

Dryer, pan, heavy-duty (p. 135). Technical data from Bethlehem Foundry & Machine. **Circle 50.**

Dryer, "Rota-Cone" (p. 100). Specially designed for heat sensitive materials. Capacities from 1 to 500 cu. ft. Brochure C from Paul O. Abbe. **Circle 39.**

Dryers, spray (p. 27). Bulletin SW 401 from Swenson Evaporator. **Circle 139.**

Ejectors, liquid-jet (p. 25). Stocked in cast iron, bronze, stainless, PVC, Haveg, Pyrex. Bulletin 2M from Schutte and Koerting give types, sizes, capacities. **Circle 67.**

Equipment, fused quartz (p. 143). Many standard sizes and shapes of equipment components, plus custom fabrication for special needs. Catalog from Thermal American Fused Quartz. **Circle 31.**

ubject guide to advertised products and services
RCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

Equipment, process, graphite (p. 31). Heat exchangers, valves, pumps, etc. in impervious graphite. Data from Falls Industries. **Circle 5.**

Equipment, tantalum (p. 97). Bayonet heaters, tapered condensers, thermowells. Data from Fansteel Metallurgical **Circle 19.**

Feeders, bulk material (p. 5). With or without automatic timing controls. Data from B. F. Gump on the Draver feeder. **Circle 81.**

Filter Papers (p. 98). Technical data and free samples from Eaton-Dikeman. **Circle 107.**

Filter Presses (p. 147). Catalog from D. R. Sperry. **Circle 55.**

Filtering Equipment (p. 140). Data from Filpaco Industries on complete line of filters, filter materials, tanks, mixers, and fillers. **Circle 120.**

Flash Drying Systems (p. 95). Application data from Raymond Div., Combustion Engineering. **Circle 41.**

Flow Meters, magnetic (p. 119). Linear measurements accurate to plus or minus 1% across the entire scale. Bulletin 20-14 from Foxboro. **Circle 24.**

Heat Exchangers (p. 4). Data from Downingtown Iron Works on fabrication and inspection facilities. **Circle 96.**

Heat Exchangers (p. 117). Technical data from Patterson-Kelley. **Circle 82.**

Heat Exchangers (p. 134). In all grades of carbon, alloy, and stainless steel, nickel, aluminum, special low-temperature materials. General Catalog from Engineers and Fabricators. **Circle 12.**

Heat Exchangers (p. 135). Technical data from Heat Exchanger Div., Western Supply. **Circle 46.**

Heat Exchangers (p. 145). The "Aero" exchanger is almost independent of external water supply or disposal. Bulletin 132 from Niagara Blower. **Circle 14.**

Heat Exchangers, coil-type (p. 122). Bulletin R-50 from Aerofin describes Type R removable-header water coils. **Circle 1.**

Heat Exchangers, shell-and-tube (p. 94). Large assortment of models available immediately from stock. Catalog 1258A from Young Radiator. **Circle 33.**

Heat Exchangers, standardized (p. 143). Bulletin from Manning & Lewis. **Circle 43.**

Jet-Venturi Equipment (p. 86). Data from Croll-Reynolds on compressors, condensers, heaters, pumps, mixers, reactors, absorbers, scrubbers, etc. **Circle 138.**

Linings, rubber or plastic (p. 8). Custom-made for special processing equipment. Bulletin CE-53 from American Hard Rubber. **Circle 20-2.**

Mills, grinding, impact (p. 142). Free test runs on your material. Data from Entoleter Division of Safety Industries. **Circle 3.**

Mill, grinding, roller-type (p. 32). Bulletin 52-40 from Hardinge gives details of the "Disc-Roll" mill. **Circle 52.**

Mixers (p. 126). Technical info from Gabb Special Products on the "Shear-Flow" mixer, for blending, dispersing, homogenizing. **Circle 127.**

Mixers (p. 131). Technical data from Chas. Ross & Son on variety of models. **Circle 150.**

Mixers (p. 139). Complete line from lightweight portables to heavy-duty. Bulletin 530 from Eastern Industries describes portables with ratings from 1/20 to 3 hp. **Circle 7.**

continued on page 112

MATERIALS *from page 109*

and data on 82 compressed gases and gas mixtures, plus regulating equipment. Catalog from Matheson. **Circle 36-1.**

Glass, gauge (p. 144). In any length or finish from 2 mm O.D. to 7 in. O.D. Data from Swift Glass Div., Swift Lubricator. **Circle 4.**

Heat Transfer Medium (p. 130). Engineering Data Book from Thermon Mfg. describes non-metallic adhesive compound with efficient heat transfer properties. **Circle 13.**

Lubricant, chemical (p. 10). Loosens frozen equipment parts. Data from Kano Laboratories on "Kroil." **Circle 16.**

Packings (p. 144). Technical data from Greene, Tweed on "Palmetto" packings. **Circle 141.**

Polyacetylenes, nonconjugated (p. 87-88). Data from U. S. Industrial Chemicals on synthesis by new low-cost process. **Circle 126-2.**

Saran (p. 128). Bulletin from Pyramid Plastics lists Saran pipe, nipples, and fittings, tubing, tube fittings, sheets, rods. **Circle 34.**

Steel, stainless (p. 13). Plates, heads, rings, circles, flanges, forgings, bars and sheets. Info from G. O. Carlson. **Circle 22.**

Sulfur (p. 29). Solid and molten sulfur ready for shipment by truck, tank car, barge, ship, or rail. Data from Texas Gulf Sulphur. **Circle 45.**

Anhydrous Ammonia
Anti-Corrosion Liquid
Brine
Caustic Catalyst
Caustic, 50% Solution
CO_2, Liquid
Diethylene Glycol
Di-propargyl Ether
Hydrocarbons

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Nickel Catalyst Slurry
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Pulp Density Mineral Ore
Silica Gel
Slurry
Sulfuric Acid
Tanning Solution
Urea
Water

Where the pressures are high . . . or the liquids are tough to handle . . . that's for us!

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For more information, turn to Data Service card, circle No. 18

CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 110*

Mixers (p. OBC). Bulletin 109 from Mixing Equipment is condensed catalog showing all types. **Circle 47-6.**

Mixers, laboratory and small batch (p. OBC). Bulletin 112 from Mixing Equipment. **Circle 47-5.**

Mixers, portable (p. OBC). ⅛ to 3 hp. Bulletin 108 from Mixing Equipment. **Circle 47-3.**

Mixers, side entering (p. OBC). 1 to 25 hp. Bulletin 104 from Mixing Equipment. **Circle 47-4.**

Mixers, top entering (p. OBC). Propeller types, ¼ to 3 hp. Bulletin 103 from Mixing Equipment. **Circle 47-2.**

Mixers, top or bottom entering (p. OBC). Turbine, paddle, and propeller types, 1 to 500 hp. Bulletin 102 from Mixing Equipment. **Circle 47-1.**

Nozzles, spray (p. 106). Over 12,000 standard nozzle types and capacities. Catalog 24 from Spraying Systems. **Circle 2.**

Nozzles, spray (p. 142). Comprehensive Spray Nozzle Catalog from Binks Mfg. **Circle 21.**

Ovens, industrial (p. 129). Special engineering of heater, fans, ducts, ports guarantees proper amount of heated air at controlled temperature. Data from Despatch Ovens Co. **Circle 53.**

Packing, tower (p. 38). Bulletin S-29R-1 from U. S. Stoneware has engineering data on applications of Intalox Saddle packing. **Circle 130.**

Pails, polyethylene-lined (p. 87-88). For safe packaging of corrosive liquids. Data from U. S. Industrial Chemicals. **Circle 126-6.**

Piping, high-impact, rubber-plastic (p. 8). In ½ to 6 in. sizes, screw or solvent-welded fittings. Valves ½ to 2 in. Bulletin 80A from American Hard Rubber. **Circle 20-1.**

Processor (p. 137). Technical data from Kontro on thin-film, tapered processor. **Circle 76.**

Pulverizers (p. 7). Bulletin 51A from Pulverizing Machinery Div., Metals Disintegrating, has complete technical details on the "Mikro-Pulverizer" line. **Circle 117.**

Pulverizers (p. 99). Data from Strong Scott Mfg. on the "Pulvocron," an advanced impact and air attrition pulverizer combined with internal particle size classifier. **Circle 75.**

Pumps (p. 111). Standard models from 25 to 2,500 hp, pressures to 50,000 lb./sq. in. Technical data from Aldrich Pump. **Circle 18.**

Pumps (p. 108). Data from Eco Engineering on small gear, rotary, and centrifugal models. **Circle 129.**

Pumps (p. 147). Technical data from Nagle Pumps on custom-built models for abusive applications. **Circle 44.**

Pumps, canned (p. 115). For pressures to 5,000 lb./sq. in., temperatures to 1,000°F, capacities to 600 gal./min. Composite Bulletin 1100 from Chempump Div., Fostoria Corp. **Circle 72.**

Pumps, controlled-volume (p. 33). Bulletin 59 from Lapp Insulator has typical applications, flow charts, specifications, special leakage chart. **Circle 29.**

Pumps, gear (p. 131). Bulletin G-1 from Schutte and Koerting. **Circle 83.**

Pumps, peristaltic-action (p. 144). Complete info on sizes and capacities from Sigmamotor. **Circle 9.**

Pumps, turbine-type (p. 23). Pump, turbine, and controls in one packaged unit. Booklet from Coffin Turbo Pump. **Circle 97.**

Pyrometers, surface (p. 139). Bulletin 4257 from Illinois Testing Laboratories describes Alnor portable "Pyrocons" for scale ranges to 2,000°F. **Circle 42.**

Seals, gas (p. 157). For leak-proof joints at pressures to 20,000 lb./sq. in., temperatures to 1,000°F. General Bulletin 160WH from General Hermetic Sealing. **Circle 25.**

Sizing Machines (p. 136). Booklets from Simon-Carter give details of precision graders, disc separators, etc. **Circle 30.**

Stills, molecular (p. 105). Brochure from Arthur F. Smith "Molecular Distillation with the Rota-Film Still." **Circle 118.**

Tanks (p. 139). New 16-page Catalog from Littleford Bros. gives details of all kinds, shapes, sizes. **Circle 6.**

Tanks, wood (p. 24). Lined and unlined in all sizes for storage of acids and other corrosive chemicals. Data from Wendnagel. **Circle 77.**

Tubing, polyethylene (p. 87-88). Data from U. S. Industrial Chemicals on new method for improving clarity. **Circle 126-1.**

Valves, "Flo-Ball." (p. 19-22). Technical data from Hydromatics gives details of new "Flo-Ball" design, for pressures to 300 lb./sq. in., temperatures to 400°F. **Circle 125.**

Valves, gate, jacketed (p. 138). Bulletin J-57 from Hetherington & Berner. **Circle 59.**

Valves, split-body (p. 26). Complete technical data from Annin. **Circle 149.**

Vessels, titanium-clad (p. 87-88). Data from U. S. Industrial Chemical on new bonding and welding methods. **Circle 126-3.**

Valves, plastic (p. 8). In PVC, rubber-plastic, polyethylene, Saran. Sizes ½ to 2 in. Technical data from American Hard Rubber. **Circle 20-3.**

Water Treatment Equipment (p. 10). Complete plants for demineralization, dealkalizing, clarification, silica removal, water softening, iron and manganese removal Catalog from Hungerford & Terry. **Circle 11.**

SUBJECT GUIDE to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT

301 Absorber, surge. Bulletin SK-59 from Hydril Co. presents specifications for Type "K" surge absorbers for removing the shock and pulsation from pipelines.

302 Centrifuge. Bulletin from De Laval Separator Co., describes new line of centrifugal "De-sludgers" for continuous removal of solids from suspensions and slurries.

303 Compressor. Cooper-Bessemer is-

continued on page 114

MATERIALS

361 Aluminum. Twenty-page Booklet from Olin Mathieson gives comprehensive information for selecting aluminum alloys and surface finishes for industrial building applications.

362 Antioxidants. Eastman Chemical Products offers new 26-page Catalog No. G-109 with properties, applications, evaluation info, handling procedures for line of food-grade antioxidants.

363 n-Butyronitrile. Eastman Chemicals

continued on page 114

SERVICES

383 Fabrication, process equipment. Folder from Goslin-Birmingham shows process equipment, evaporators, filters and facilities for custom manufacture.

384 Industrial Water. Reprints of Technical Paper 138 entitled "Problems in the Use of Sewage Plant Effluent for Boiler and Cooling Purposes" from Betz Laboratories.

385 Rubber, synthetic. Description of plant for making critical synthetic rub-

continued on page 114

For more information, circle No. 26 ➤

One of a series

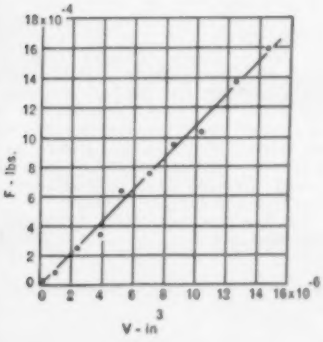
On the riddle of rolling friction

It doesn't take much to roll a hard ball across a hard, smooth, level surface – actually only about 0.00001 times the normal force acting vertically on the ball. But by careful measurement of this tiny rolling force, scientists at the General Motors Research Laboratories are helping to unravel the riddle of rolling friction.

An important relationship recently uncovered in this fundamental study: the rolling force is proportional to the volume of material that is stressed above a certain level. As a result, a GM Research group have not only confirmed the hypothesis of *how* a rolling ball loses energy (Answer: elastic hysteresis) but also have learned *where* this lost energy is dissipated (Answer: in the interior of the material, not on the surface). Mathematical analyses have indicated the exact shape of the elastically stressed volume in which all the significant frictional loss takes place.

The purpose of friction research at the GM Research Laboratories is to learn more about the elastic and inelastic behavior of materials. This knowledge – of academic interest now – will eventually give GM engineers greater control of energy lost through friction. This is but one more example of how General Motors lives up to its promise of "More and better things for more people."

General Motors Research Laboratories
Warren, Michigan



Relationship of rolling force to elastically stressed volume.

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORresponding NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 112*

sues 6-page Bulletin 92 on 300 hp. packaged pickup compressor.

304 Compressors, turbocharged. New Bulletin 179 fully describes and illustrates the Clark Bros. line of turbocharged HRA-T gas-engine-driven compressors.

305 Computer. Data available for RPC-4000 electronic, transistorized, internally binary magnetic drum computer from Royal McBee.

306 Computer, analog. Brochure describes solid state computing device for mathematical calculations in the chemical process industries. Info. from Southwestern Industrial Electronics.

307 Computer, programming. Technical info available in 18-page Booklet from Royal McBee for new programming developments for computers.

308 Crusher, saw tooth. Information concerning a water-tight saw tooth crusher for handling chemical slurries is available from Sprout, Waldron & Co.

309 Detector, chlorine. Bulletin No. 0805-2 from Mine Safety Appliances describes operation of new instrument for checking chlorine concentrations to 20 ppm in air.

310 Detector, hydrocarbon. Eight-page Brochure describes operation, use and specs for Model 213 hydrocarbon detector for detecting ppm of aldehydes, ketones, alcohols and amines. Info. from Perkin-Elmer.

311 Detectors, leak, halogens. Technical Bulletin GET-2936 from General Electric gives detailed instructions on finding leaks using new, portable halogen leak detectors.

312 Equipment, corrosion resistant. Four page technical Bulletin DS-1 from Resistoflex describes chemically inert Fluoroflex-T dip pipes, spargers, thermowells, and nozzle liners.

314 Equipment, processing. Literature describing process equipment such as high pressure filters and "Turba-Film" processor are available from Rodney Hunt Machine.

315 Equipment, processing, graphite. New 29-page booklet contains data for cost estimation of standard impervious graphite processing equipment produced by Falls Industries.

316 Equipment, refractory metals. New 8-page Bulletin No. 978 from Pfaudler describes equipment available using tantalum, titanium, and zirconium as materials of construction.

317 Filter. Catalog Sheet 111 describing 2-micron filter for ultra-fine particles available from Bendix Aviation.

318 Filter, acid sludge. Bulletin 459 from Milton Roy Co. describes sludge trap and filter for removing concentrated sulfuric acid sludge.

319 Filters, drum. Bulletin from Peterson Filters and Engineering Co. presents

continued on page 116

MATERIALS *from page 112*

offers information and samples for this newly produced solvent and chemical intermediate.

364 Cryolite, natural. Illustrated 24-page Booklet on history, physical, chemical properties, uses of natural cryolite from Pennsalt Chemicals.

365 Esters. Kessler Chemical offers 39-page Catalog containing specifications, physical properties, technical data, literature references for a variety of industrial esters.

366 Hydroxyethyl Cellulose. New 16-page Booklet containing extensive data on properties, materials preparation, applications, test methods for hydroxyethyl cellulose from Union Carbide.

367 Inhibitors, acid. Bulletin from Amchem Prod. contains Table showing protection "Rodine" acid inhibitors afford various metals.

368 Insulation. New 54-page Catalog IN-244A contains physical properties, thermal data, and product information for complete line of thermal insulation materials. Data from Johns-Manville.

369 Insulation, neoprene. Information concerning preformed, flexible neoprene insulation for straight or bent pipe from Grant Wilson, Inc.

370 Laminates, plastics. Information concerning properties and applications of "Daponite" laminates from Food Machinery and Chemical.

371 Materials, plastics, chemicals. New 12-page Booklet CDC-370 describes and gives technical data for complete line of polycarbonate, phenolic resins; varnishes; molding powder; fused magnesium oxide. General Electric.

372 Molybdenum. New 12-page brochure describing applications, physical properties and production processes for molybdenum from Sylvania Electric Products.

373 Organic Chemicals. A complete list of organic chemicals readily available; a complete list of organic chemicals in development stage with estimated prices; and Brochure for custom synthesis from Eli Lilly.

374 Plastics. New 67-page Catalog from Plastics Division of Kaufman Glass includes prices, dimensions, table of properties for complete line of plastic materials.

375 Plastics, polyvinyl chloride. New process prevents degradation of PVC thus expanding the use for handling corrosive liquids. Information from General American Transportation.

376 Polyethylene. Technical information from Phillips Chemical contains 20-page Brochure with physical, chemical properties, processing, application data for polyethylene.

377 Polyethylene, low molecular weight. Three new polyethylene resins for a variety of uses from Eastman Chemical Products. Properties and uses.

378 Polyethylene, pellets. Information concerning availability of high quality reprocessed polyethylene film in dense pellet form from Interplastics Corp.

379 Polymer, acetal resin. New high-melting thermoplastic material having unusual properties is being used for replacement of brass and other metals in valve construction. Data from DuPont.

380 Radiochemicals. New 46-page Catalog lists Carbon-14 labeled compounds manufactured by Research Specialties Co. along with prices, licensing info, purity methods, etc.

381 Resin, epoxy. Data concerning development of an epoxy resin with high temperature performance from Dow Chem.

382 Sulfur Dioxide. New 16-page Bulletin from Ansul Chemical Co. describes techniques for storage, handling, transferring liquid sulfur dioxide.

DEVELOPMENT OF THE MONTH

ELECTRONIC COMPUTER

(Circle 601 on Data Post Card)

New advance in electronic computers is claimed by Computing Systems, Inc. with its incorporation of high-speed memory and automatic iteration capability in a general purpose analog computer.

The new system, known as DYSTAL (Dynamic Memory & Storage Analog Computer), is said to utilize the traditional advantages of both analog and digital computers. The analog's speed, lower cost, ease of programming, and improved output data presentation are reported to be combined with the digital computer's unique capacity for data storage and time-sharing of computing elements.

For more complete details, Circle 601 on Data Post Card.

SERVICES *from page 112*

ber parts for valves and regulators from Grove Valve and Regulator.

386 Tubular Products, report on nondestructive testing. A review of testing procedures for tubular products from Republic Steel.

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FIELD-PROVED DESIGN

The basic design of Chempump, the first canned pump, has been tested and refined under tough field conditions for nearly ten years.

RESULT: Leakproof pumping which requires no seals, stuffing box, no "O" rings. Easy bearing changes without breaking pipeline connections. Special designs and materials available for handling fluids with pressures to 5000 psi . . . temperatures to 1000°F . . . capacities to 600 GPM. Water or steam jackets available to insure proper operation in many special applications. Most models UL approved.

Chempump is *the* canned pump proved in thousands of successful installations, ranging from heavy water to corrosive slurries. You can rely on Chempump to handle your costly, volatile, toxic, or other problem fluids safely, efficiently and economically. *Write now for composite bulletin 1100.*

Chempump Division, Fostoria Corporation, Buck and County Line Roads, Huntingdon Valley, Pennsylvania.

CHEMPUMP. *first in the field . . . process proved*

For more information, turn to Data Service card, circle No. 72

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 114*

typical installation and applications of variety of drum filters.

320 Filters, vacuum. Bulletin from Proportioneers Div. of B-I-F Industries describes both concentric and flat leaf vacuum filter for industrial process water.

321 Fittings, jacketed. New Catalog from J. P. Devine Manufacturing gives diagrams, sizes, other information for jacketed fittings, gate valves, plug cocks, expansion joints, strainers.

322 Heat Exchangers, graphite. Details for new Heil "Nocordal" impervious graphite heat exchanger for cooling, heating sulfuric and other acids from Heil Process Equipment.

323 Hose, pressure. Information available on new line of flexible metal pressure hose in wide range of matarials available from International Metal Hose.

324. Hose, pressure. Information concerning new, lightweight, flexible, high pressure nylon hose for a variety of industrial applications from Polymer Corp.

325 Indicator, motion. New literature from Bin-Dicator gives details for "Roto-Guard," positive motion indicator safety mechanism.

326 Instrumentation, gas chromatography. Data Sheet 10.15-20 from Minneapolis-Honeywell gives information for programming temperature in gas chromatographic measurements.

327 Instrumentation, industrial waste. Industry Bulletin B97-2 from Minneapolis-Honeywell is a 24-page collection of technical articles concerning waste treatment problems.

328 Joints, swing. Catalog F-8 from OPW-Jordan gives dimensions, materials of construction, service instructions for line of swing joints.

329 Laboratory Ware, fused quartz. New 30-page Catalog contains stock items available in fused quartz from Thermal American Fused Quartz Co. Physical properties and price list are included.

330 Meters, flow. Information for positive displacement rotary type meter for variety of fluids from the Flow Equipment Co.

331 Mills, grinding. New "Vibro-Energy" equipment for precision grinding of chemicals, pigments, and metal powders in sub-micron range available from Southwestern Eng.

332 Mills, jet. Information concerning new jet mill which eliminates contamination in grinding is available from Trost Jet Mill in lab or production sizes.

333 Mixer, batch. Details are available from Daffin Mfg. on line of batch mixers for blending of dry, free flowing materials.

334 Mixer, ribbon blender. Information on new ribbon blenders with capacities of 20 to 200 cu. ft. for solving mixing problems from Munson Mill Machinery.

335 Motor Reducers. New 28-page Catalog MR-58 is a complete selection guide for vertical motor reducers and in-line reducers. Philadelphia Gear.

336 Piping, graphite. Catalog from Falls Industries presents properties, specifications, installation tips for graphite pipes, fittings, valves.

337 Pumps, centrifugal. Bulletin HY-856-A from Bell & Gossett has selection table for "Uni-built" centrifugal pumps.

338 Pumps, centrifugal. New type "pH" centrifugal pumps for corrosive liquids and slurries handling outlined in Dean Brothers Circular 217.

339 Pumps, chemical. New Bulletin 1100 describes complete line of sealless pumps for handling a variety of chemicals from Chempump Div. of Fostoria Corp.

340 Pumps, chemical. New low-cost compact "canned" pump weighs 7 lb., pumps 800 gal./hr., produces heads to 12 ft. Data available from Dynapump Div., Fostoria Corp.

341 Pumps, chemical. New proportioning pump for corrosive chemicals from B-I-F Industries.

342 Pumps, filter. Informative filter pump selection guide from Sethco Mfg. presents 20 models for 50 to 2700 gal./hr. capacity for variety of electroplating and industrial solutions.

343 Pumps, gear. Application, construction and operation of SK Gear Pumps presented in Bulletin G-1 from Schutte and Koerting.

344 Pump, metering. Bulletin 1153-C describes the "Mersemetric" controlled volume metering pump with submerged liquid inlet. Milton Roy.

345 Pumps, rotary. Bulletin One from Blackmer Pump gives details for selection, application and construction features for rotary power-driven pumps.

346 Pumps, vacuum. Information from Ingersoll-Rand presents advantages, applications of the "Axi-compressor" for vacuum service.

347 Purifier, hydrogen palladium diffuser. Information for producing ultrapure hydrogen from dissociated ammonia using palladium diffusion purifier from Engelhard Industries.

348 Regulators, sliding gate. Condensed Catalog from OPW-Jordan gives info for sliding gate regulators and control valves.

349 Rotameters. Bulletin 150 from Brooks Rotameter presents types, materials of construction and adaptability of rotameters for corrosive service.

350 Rotameters. New Bulletin 18N describing pneumatic transmitting rotameters for transmitting fluid flow rates to recording instruments from Schutte and Koerting.

351 Safety, fire. New 27-page Catalog from Fyr-Fyter Co. lists complete line of safety equipment for detection and controlling interior fires.

352 Separator, centrifugal. New multistage, push-type centrifugal separator for filtering wide variety of materials in chemical process industries. Details from Baker Perkins.

353 Spray Dryers. Editorial reprint SP of case study of spray drying of alumina granules from Bowen Engineering.

354 Tanks, chemical processing. Bulletin 59 illustrates wood tanks and towers available from Wendnagle for the chemical process industry.

355 Tester, metals. A simple, unique tester which differentiates between similar metals such as Inconel, stainless steel; zirconium, hafnium and Zircaloy-2. General Electric.

356 Thermocouple Wire, noble metal. New Brochure from Baker Platinum Div. of Engelhard Industries presents materials information for temperature sensing elements.

357 **Valves.** Bulletin V-1 illustrates and describes some current valves manufactured by Schutte and Koerting.

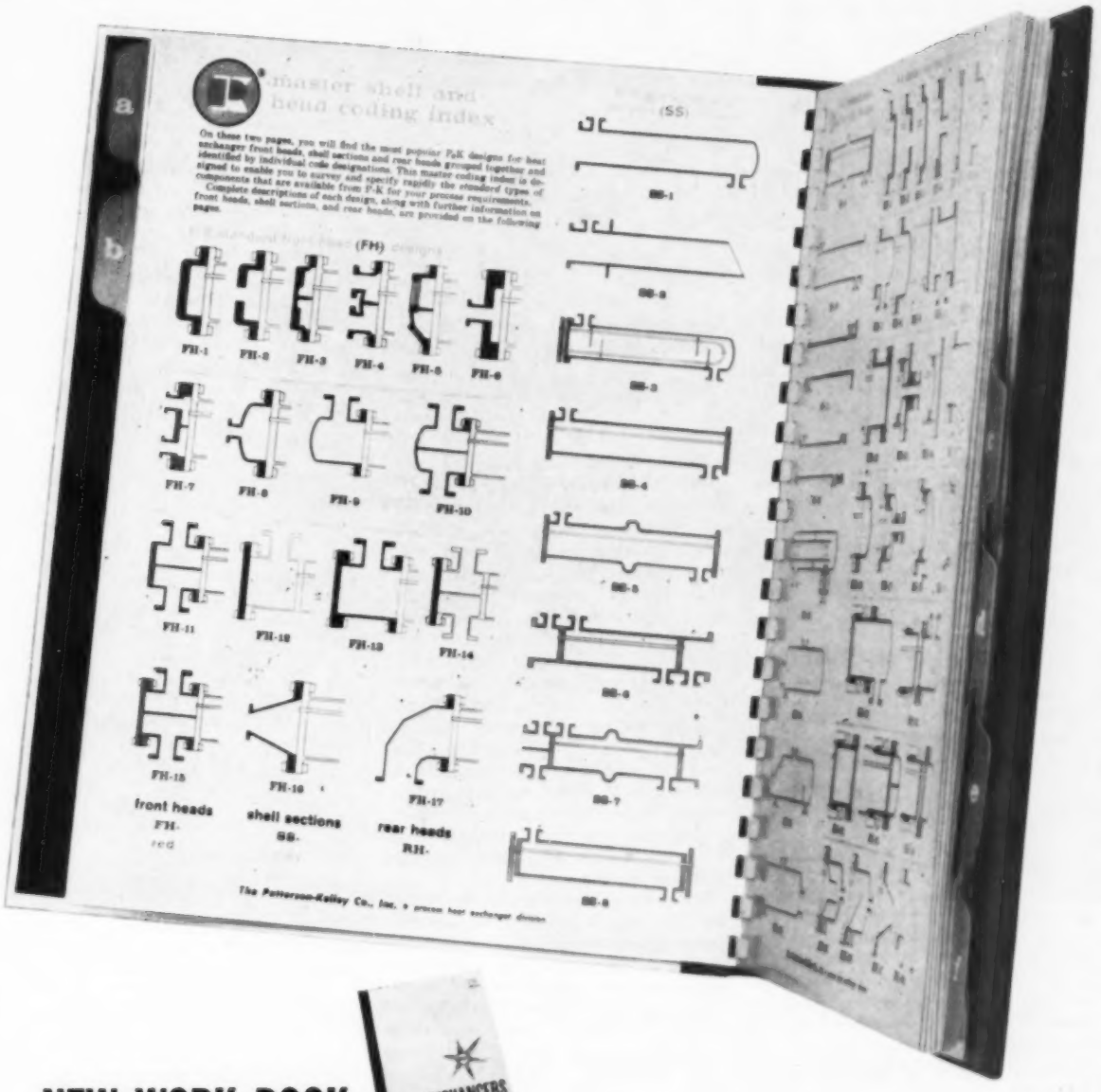
358 Valves, flow control. Catalog containing specifications for motorized iris flow control valve featuring flexible diaphragm for bulk material flow in hoppers from Syntron.

359 Valves, non-lubricated, gate. Brochure from Pacific Valves describes new valves featuring dual metal-to-metal and elastomer seals for light gases or heavy fluids.

360 Valves, reduced ports. Literature from Red Jacket Co. describes rubber pinch valve adaptable to control problems.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 600 on Data Post Card.



NEW WORK BOOK SIMPLIFIES HEAT EXCHANGER SELECTION

The need for a standard terminology to simplify communications between P-K and engineers in the chemical processing industry has been met in P-K's new Heat Exchanger Manual.

This unique communications tool illustrates and describes components of shell and tube heat exchangers commonly used in processing. A complete system of interchangeable front heads, shells and rear heads is established. Fundamentals of heat transfer and design are reviewed. Even economic considerations are discussed. The simple, certain nomenclature saves time, effort and duplication of engineering work.

This 120-page manual, indexed and bound in hard covers, will be supplemented from time to time with new technical material. Names of holders will be registered to receive such material as it appears.

Only a limited number of copies is available and, naturally, these should go to those in the process industries who will benefit most from the information we have compiled. If you design or specify heat exchangers, write us on your company letterhead, outlining briefly areas of your interest. A few copies are available to students and non-technical personnel at a nominal charge. Patterson-Kelley Co. Inc., E. Stroudsburg, Pa.

Patterson Kelley
Heat Exchanger Division

For more information, turn to Data Service card, circle No. 82

industrial news

W. A. Samuel, *Callery Chemical Co., Callery, Pa.*

Small quantity diborane production

Details of a pilot facility at Callery Chemical for production of up to 100 pounds of diborane per day.

The process used at Callery is based on the following reaction: potassium borohydride plus boron trifluoride to give potassium fluoroborate and diborane. Diethylene glycol dimethyl ether (diglyme) is used as a solvent.

$$3\,KBH_4 + 4\,BF_3 \xrightarrow{\text{diglyme}} 3\,KBF_4 + 2\,B_2H_6$$

The reaction is carried out in 100 gallon reactors (Figure 1). These are jacketed steel vessels, each fitted with an agitator, a liquid level gage, a dip tube, and various other nozzles for instrument elements, sample connections, etc. One of the openings at the bottom of the tank feeds the suction line of a centrifugal pump which circulates the reactor contents through a refrigerated (−10°C) heat exchanger and back to the reactor. Cooling water is passed through the reactor jacket. Two units in parallel are used, so that one can be washed and recharged while the other is operating. A simplified schematic diagram of the system is shown in Figure 2.

Operating procedure

About 60 gallons of diglyme are metered into one of the reactors from one of two 150 gallon diglyme storage tanks. Meanwhile, a charge of KBH_4 is weighed out in a plastic bag. The borohydride charge may vary from 80 to 135 pounds, but 120 pounds is usually used. This material may be exposed to the air for short times without appreciable deterioration. The weighed charge is dumped into a nitrogen-blanketed hopper. This hopper is above the reactor and is connected to it by 4-inch pipe fitted with plug valves. The hopper is equipped with a gas-tight lid to prevent air from entering the system. After the charged has been dumped from the hopper into the reactor, additional diglyme (usually about 15 gallons) is added to the reactor to bring the level up to that at which it operates best.

At this point, the reactor contents are circulated through the external heat exchanger, and the flow of cooling water through the jacket is started. Then the BF_3 addition through the dip-tube is begun. The BF_3 is added rapidly (about 40 to 50 pounds per hour) until the diborane evolution begins. This usually requires one to two hours. The exact reason for this delay in diborane evolution is not known. Callery researchers have evidence that it is not due to the formation of a diborohydride, which does occur when sodium borohydride is used. The delay is probably due to a combination of solubility effects and side reactions with impurities.

After the diborane evolution begins, the BF_3 rate is reduced to about 20 pounds per hour until the borohydride charge is exhausted. The completion of the reaction takes about six to eight hours and is evidenced by the cessation of the diborane flow. Two factors limit the permissible BF_3 addition rate: the diborane condenser capacity and the temperature rise in the reactor. The temperature rise is usually the controlling factor since the reaction liberates about 1,400 BTU per pound of diborane produced, and the desired maximum temperature is 40°C. Depending on the nature and the amount of impurities in the borohydride, even more heat may be evolved. This heat is removed via the circulating loop through the refrigerated heat exchanger. Having adjusted the BF_3 rate so that the temperature is satisfactory, the reactor is on-stream.

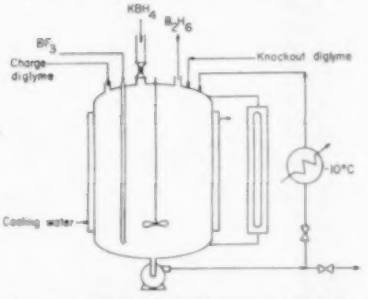


Figure 1. Schematic diagram of the diborane reactor at Callery.

Product recovery

The diborane gas being produced must now be freed of solvent and condensed before storage. The gas passes from the reactor through an entrainment trap and thence through a −10°C heat exchanger to remove most of the diglyme. This diglyme drains back to the reactor. The dibor-

continued on page 120

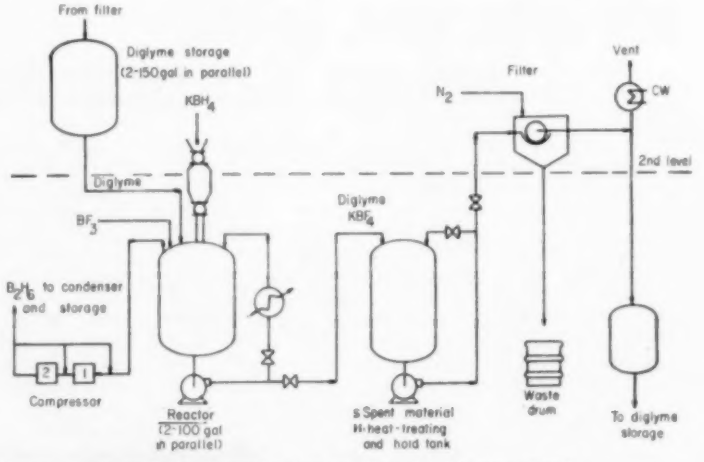
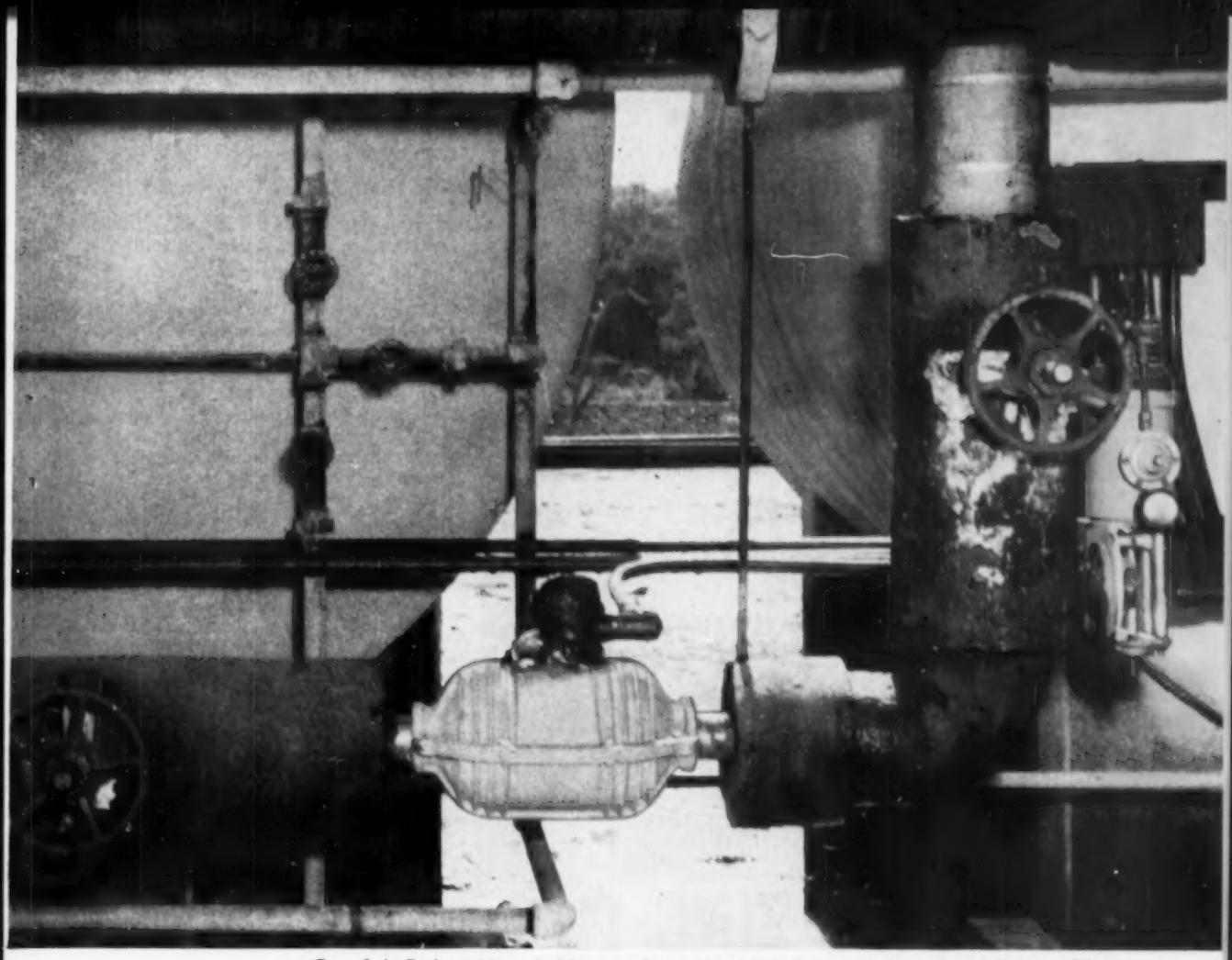


Figure 2. Simplified schematic for small-scale diborane plant.

For more information, circle No. 24



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Diborane

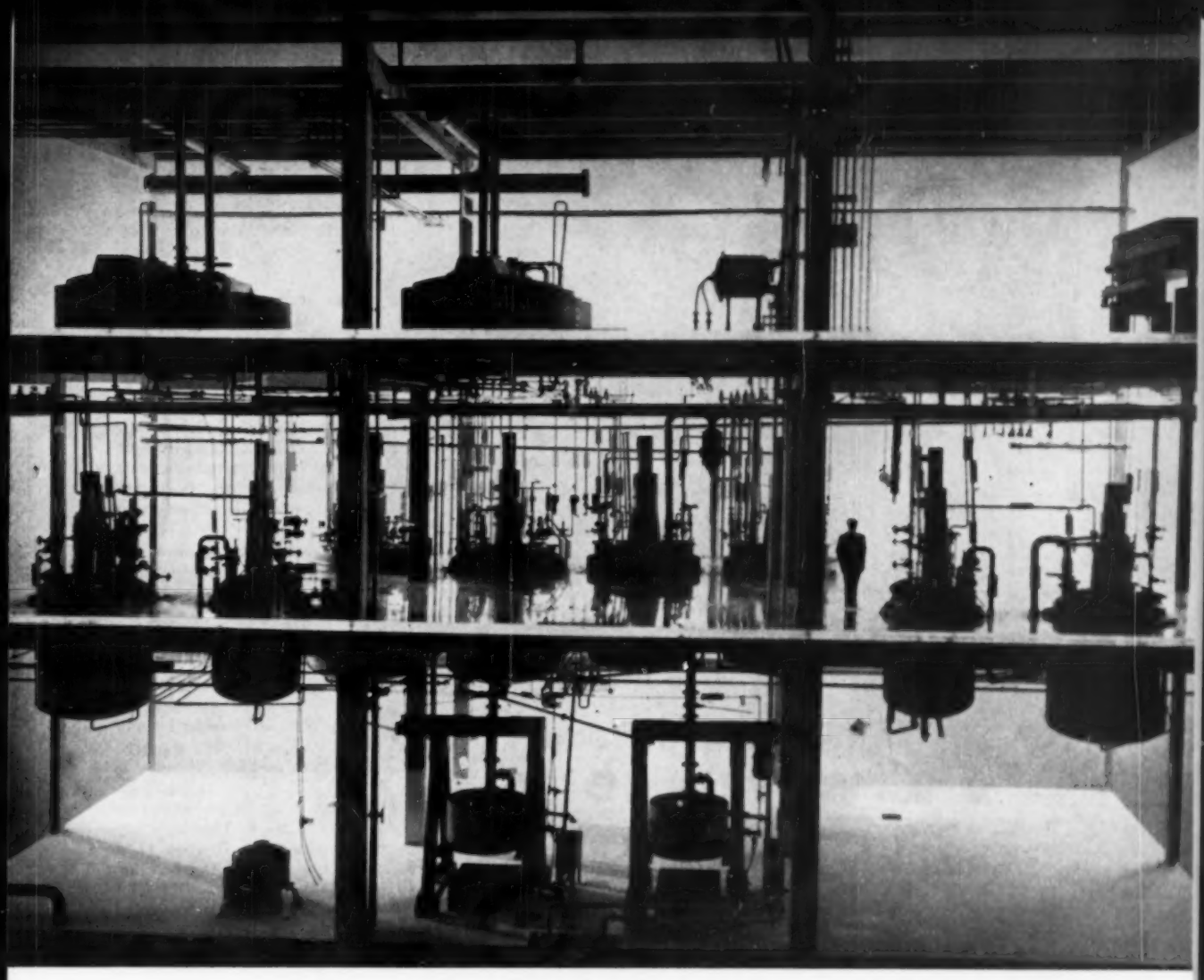
from page 118

ane then passes through a dry-ice cold trap where virtually all of the remaining diglyme is removed. This diglyme, which is small in quantity, may be recovered later. The diborane now flows through a rotameter and into a two-stage reciprocating compressor system. The discharge pressure of the first stage is 50 lb./sq.in. gauge, and that of the second stage is 125 lb./sq.in. gauge. In order to eliminate the possibility of developing a vacuum in the event that the feed gas flow drops to too low a rate, slip-streams from the discharge of each stage are recycled back to the suction side of that stage. To prevent overheating of the gas, the streams are cooled in refrigerated (−10°C) heat exchangers immediately prior to compression. At 125 lb./sq.in. gauge the diborane is condensed in Heliflow heat exchangers at −60°C. It is then stored as a liquid. During the operation, about 32 pounds of diborane will be produced. There are now left in the reactor nearly 300 pounds of waste solids suspended in the 75 gallons of solvent. The solvent is expensive and must be recovered. Meanwhile, the second reactor is started through the sequence of operations.

Solvent recovery

The solvent recovery and waste removal operation begins by transferring the spent reactor contents to a 250 gallon hold tank, after having purged the reactor with nitrogen to remove the residual diborane. The hold tank is equipped with a steam jacket and a recycle loop. The spent material, which is a slimy slurry, is heat-treated for four to eight hours at 80°C, and it is circulated at about 10 gal./min. to keep the solids in suspension. Heat-treating increases the particle size of the solids, permitting easier filtration. After the desired hold time has elapsed, a slip-stream is taken from the hold tank recycle loop and fed to a filter. The filter is a Dorr-Oliver continuous rotary pressure filter; the drum is a foot wide and a foot in diameter. The filtration is carried out at 80°C, and a differential pressure of 5 to 7 lb./sq.in. is maintained across the filter with nitrogen. Normally the filtration requires only two hours per batch, but sometimes impurities in the borohydride charge cause such poor filterability that as many as nine hours may be required. The diglyme filtrate passes through water-cooled heat exchangers and into

continued on page 122



This is a scale model of a section of a dye plant now being built by Kellogg for Toms River-Cincinnati Chemical Corporation. It is a typical example of Kellogg's ability to design with models to clients' process schemes.

NEW LIGHT ON AN OLD PROBLEM

PROBLEM: *Provide chemical companies with ways to: (1) minimize capital investments in new plants; (2) shorten the time between plant planning and plant production; (3) assure optimum design and operating efficiency.*

SOLUTION: *Kellogg-developed scale models, such as the one shown above, used as engineering and design tools.*

For an increasing number of The M.W. Kellogg Company's clients in the chemical and petroleum refining industries, scale models have proved to be a many-sided solution to the economics of engineering and constructing new production facilities. This is especially true in regard to piping—a major investment in any process plant.

Built by Kellogg's designers, these three-dimensional blueprints eliminate planning studies and piping key plans, improve designs, facilitate approval, promote faster construction and lower operating costs. They replace conventional drawings of over-all layout and piping. Photographs of the models are used instead of these drawings. The models themselves are used on the job site to save time in explaining construction details to workers and for use in training operators to run the plant.

Kellogg's model techniques and economics, as they apply to the whole plant, are described in a reprint of the 12-page Kelloggram No. 5, available on request. For those specifically interested in Kellogg's developments in process piping, also ask for the 24-page reprint of a recent Kellogg article in the chemical press, "How and When to Use Plastic Pipe".

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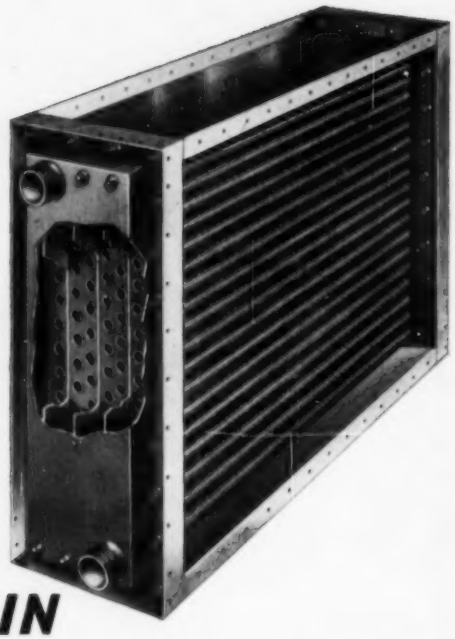

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Diborane

from page 120

an intermediate hold tank. It is later transferred to one of two 150 gallon storage tanks and reused in subsequent runs. The filter-cake drops from the filter through a chute and into a waste drum.

Materials of construction

The chemicals used in this process do not pose any severe corrosion problem. Brass must not be used because it is attacked by boron trifluoride. Aluminum is avoided because some waste products formed during washout of boron-contaminated equipment cause pitting. All other common metals may be used. Most of the lines and vessels in the plant described here are mild steel.

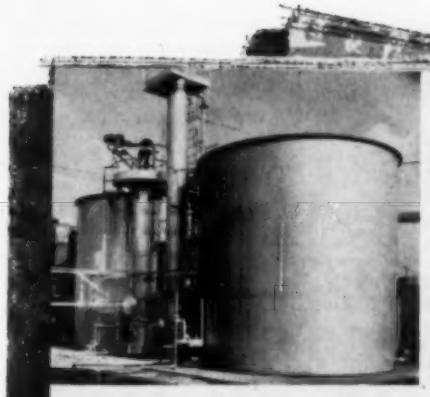
Neoprenes and natural rubbers are attacked by diborane, presenting gasket and seal problems. Kel-F, teflon, nylon, and some asbestos compoundings, however, are very satisfactory.

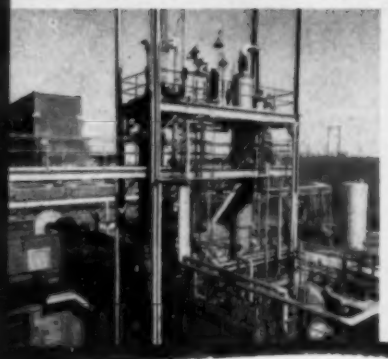
Safety precautions

Diborane is considered toxic above 0.5 ppm; the limits of flammability range from 0.8 to 98 percent by volume in air. Although the reported ignition temperature for diborane is 145°C, impurities may make high concentrations of diborane spontaneously flammable in air. This combination of characteristics makes good ventilation and explosion protection mandatory.

The operating area is provided with a normal ventilation rate of 5 to 10 air changes per hour. Provision is made for emergency ventilation at a rate of about 40 to 60 air changes per hour. Standard construction includes at least one pressure-relief wall in every structure in which diborane is processed, and explosion-proof (Class I, Group D) electrical equipment is used in all areas where diborane may be present. By combining good housekeeping with common sense and a little specialized knowledge, operations using diborane can be as safe as most other chemical processes.

The process described here is suitable for supplying diborane for experimental and development operations which, because of their varying requirements, cannot utilize the output of a truly continuous diborane plant. By the same token, it would also fulfill the needs of a batch process which used diborane on an intermittent basis, and it would satisfy the requirements for a continuous operation of moderate capacity. For large capacity operations, there are continuous diborane processes which can provide diborane more cheaply. #





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chemical feature

A. V. SLACK, *Tennessee Valley Authority*

Liquid chemical fertilizers in drastic upswing

Development of practical method for use of low-cost, wet-process phosphoric acid in mixes seen as key to further expansion.

THE FIRST BULK production plant east of the Rockies for liquid mixed fertilizers was built in 1954. Today, only six years later, it is estimated that there are 256 plants in the central and eastern part of the country. With the Far West included, there are now about 354 plants in the U. S. producing liquid mixes.

Liquid fertilizers have now advanced to a challenging position: consumption reports by the U. S. Department of Agriculture for the year ending June 30, 1958, show that one liquid form—anhydrous ammonia—was well ahead of any other nitrogen fertilizer in tonnage consumed (nitrogen basis). In fact, liquid forms of nitrogen—including anhydrous ammonia, aqua ammonia, and nitrogen solutions—accounted for about half of the total nitrogen used in direct application, even though old established fertilizers such as ammonium nitrate, ammonium sulfate, and sodium nitrate were among the solid contenders.

Advantages

Growing use of fertilizers in liquid form is to be expected as a development in keeping with modern technology. With any low cost chemical product used in large quantities, cost of handling is an important part of the over-all cost. Use of the liquid or slurry form is a growing practice in handling other heavy chemicals to reduce labor and other handling costs. In the fertilizer field, bulk handling of solutions or slurries can also simplify handling, expecially in application of fertilizer on the farm.

A second advantage of liquids, especially in regard to nitrogen materials for direct application, is that the manufacturing cost is reduced by omitting the operations of drying and granulating. Problems of caking and poor drillability are also eliminated. But, along with these advantages, the liquids bring their own peculiar disadvantages of high storage cost, corrosion, and relatively low plant food content.

Approximate locations of plants making liquid mixed fertilizer are shown in Figure 1. As evident from the map, the industry is centered in California and in the Corn Belt states of Iowa, Illinois, Indiana, and Ohio. Some expansion into other areas has taken place. There are now about 30 plants in the South Atlantic and East South Central States.

Total consumption of direct application nitrogen in 1957-58 was about 479,000 tons of nitrogen, as compared to 377,000 for ammonium nitrate, the runner-up. Nitrogen solutions are more popular in the South Atlantic and West North Central States. Total consumption of nitrogen in this form was about 100,000 tons in 1957-58.

Although no published figures are available on liquid mixes, an estimate can be made on the basis of number of plants and estimated average production. The latter is estimated at about 2,500 tons. From this, current annual production, which should parallel consumption closely, is estimated at over 800,000 tons. This probably represents about 200,000 tons of plant food, or about 4.5% of that applied in the form of mixed fertilizers.

Thus, it is clear that liquid mixes have not made the inroads in the mixed fertilizer field that anhydrous ammonia and nitrogen solutions have in the direct application field. One reason, of course, is that liquid mixes are newer in most sections than the nitrogen liquids. A major difference, however, is that the latter usually can be produced and sold at less cost than for comparable solids. This is not the situation with liquid mixes; these normally cost as much or more to make than solid mixes, and must depend on convenience and saving in handling and application as their main advantage.

Raw materials

Furnace-type phosphoric acid is still the main source of phosphate, although wet-process acid is being used in a few plants, Cold-mixing plants, which are few in number, use ammonium phosphate solution or solid diammonium phosphate.

Urea-ammonium nitrate solution appears to be the principal source of nitrogen for supplementing the ammonia required to neutralize the acid. Urea and various ammoniating solutions are also used, and in the Far West, ammonium nitrate continues to be a leading source of supplemental nitrogen.

Practically all the potash is supplied as potassium chloride. However, limited use of potassium hydroxide has been noted recently, mainly to reduce the chloride content in tobacco fertilizers.

Supplies of all raw materials seem adequate with the exception of phosphoric acid. It is reported that the supply of both furnace and wet-process acid has been limited during the current production season, especially

continued on page 126

Figure 1. Location of liquid mixed fertilizer plants in 1960.

ENGINEERS AND CONSTRUCTORS FOR INDUSTRY

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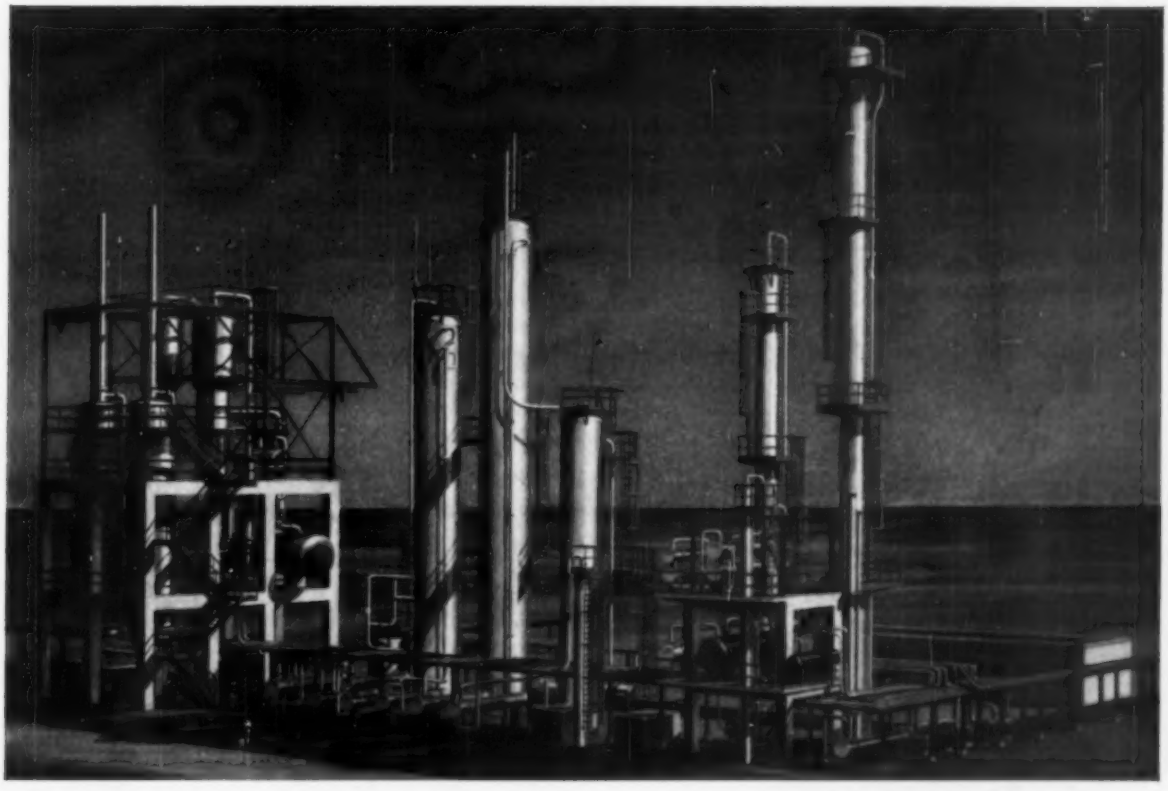

Olin Mathieson Chemical Corporation's new ethylene oxide plant at their Doe Run works, at Brandenburg, Kentucky is scheduled to go on stream late in 1960.

Engineered and constructed by The Lummus Company, the plant will employ the Shell Development Company's process for the direct oxidation of ethylene to ethylene oxide. The ethylene oxide product will be converted into derivatives for use in the manufacture of antifreeze, industrial coolants, hydraulic brake fluids, detergents and chemical intermediates.

Feed for the new plant will come from Olin Mathieson's ethylene plant, also located at Doe Run.

The new plant is part of a recently announced $30 million expansion program for Olin Mathieson's Chemicals Division. It is the fourth Shell process ethylene-oxide plant, to be designed, engineered and constructed by Lummus in the last several years. The other three are operated by Calcasieu Chemical Corporation, at Lake Charles, La.; Wyandotte Chemical Corporation at Geismar, La.; and Petrochemicals, Ltd. at Partington, England.

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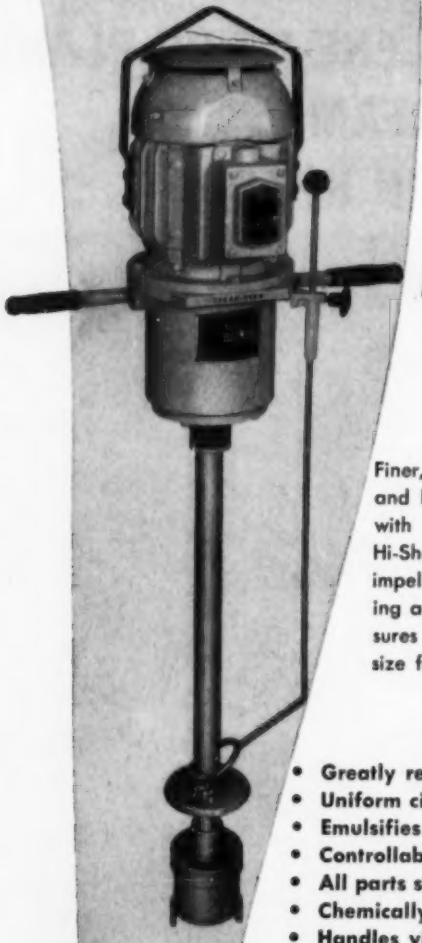

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Chemical fertilizers

from page 124

in the Midwest. The acid is said to be in such demand in the solid fertilizer industry for use in granulation that production and shipping facilities have not been adequate to meet the needs of all consumers.

Grade limitations

A continuing problem is the relatively low analysis attainable in liquid mixes as compared to solid mixes. Coupled with this is the lack of good data on what grades can be made with available materials. Work at Sohio Chemical has included a study of the effect on solubility resulting from varying the ratio of urea to ammonium nitrate in the supplemental nitrogen. In work at TVA, a method has been worked out whereby the maximum grade stable at 32°F can be estimated for any nutrient ratio. Also, by use of a formula developed in this work, salting out temperature for particular grades can be estimated.

More data are needed on solubility in liquid mixed fertilizer systems, in particular on solutions in which part or all of the potassium chloride is replaced with potassium hydroxide.

Increasing nutrient content

Work at Sohio has shown that use of ammonium nitrate along with the urea raises the grade for some nutrient ratios, the optimum amount varying with the ratio. In many instances, however, addition of ammonium nitrate reduces solubility.

The NH_3:H_3PO_4 ratio has a significant effect on solubility in grades low in potash. General practice is to use a mole ratio of 1.7, whereas 1.6 or 1.5 usually gives a somewhat higher grade.

Use of superphosphoric acid (76% P_2O_5) gives a large increase in solubility, especially in grades low in potash. An 11-35-0 base solution made from superphosphoric acid is also being used to some extent in cold-mix operations.

For grades containing potash, solubility can be increased by using potassium hydroxide or potassium carbonate rather than potassium chloride. However, these materials are so much more costly than potassium chloride that use of them merely to increase concentration is quite limited.

Concentration can be increased by exceeding the solubility of the nutrient salts and treating the salted out constituents to produce a stable suspension. Salting out is then no longer a major difficulty, but problems in ap-

plying the product are introduced. Very high grades can be produced in this manner, but much more work is needed before the practicality of the method is established and producers can use it with any assurance of success.

In addition to the problem of limited concentration, liquid fertilizer producers are not able to make some of the popular nutrient ratios because of their high acidity, for example: 1:4:4, 1:6:6, 1:4:2, and 0:1:1. Such ratios can be made by replacing part or all of the potassium chloride with potassium hydroxide.

Process economics

One of the main advantages of the liquid route to fertilizer production is the relatively low investment required for plant equipment. Elimination of operations such as granulation, curing, fume disposal, and bagging simplifies production considerably. However, many producers have found it necessary to invest heavily in distribution and application equipment in order to sell their product. Thus the total investment can be considerable—reportedly over $200,000 in some instances.

Raw material costs

The trend is to use of urea-ammonium nitrate solution rather than urea as a means of reducing cost for supplemental nitrogen, even though the grade is usually lowered thereby. The main raw material cost problem, however, has to do with phosphate. The lower cost of wet-process acid in most areas has led to a major effort in finding ways to use it, including purifying of the acid, and precipitation, sequestration, or suspension of the impurities.

Australia's first carbon black facilities have been completed. The 30 million pound capacity plant built by United Carbon, near Altona, will be able to supply most of Australia's oil furnace black requirements.

A 13 million pound annual capacity oriented polyolefins plant marks Goodrich-Gulf Chemicals first venture into the manufacture of polymers other than elastomers. The Port Neches, Texas, installation will use the Ziegler process.

Allied Chemical has acquired 51 percent of the shares of The Montrose Exploration Company Ltd., United Kingdom, chrome ore deposit and mine owning firm. Shares in the Transvaal will be held by Allied's South African subsidiary, Allied Mining South Africa.

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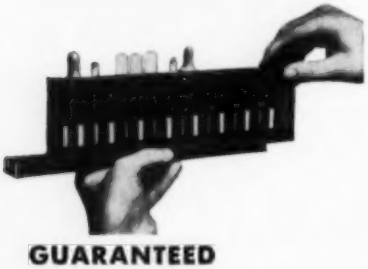

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Prahl wins Achievement Award of Western New York Section

"Few would-be inventors are frustrated by lack of imagination or intellect, but are rather defeated by lack of patience, of willingness to defy the opinions of others, to fight for their ideas," said **Walter H. Prahl** in his award acceptance address to A.I.Ch.E's Western New York Section. Prahl, director of Phenol Research and Development of the Durez Plastics Division of Hooker Chemical, recently received the Eighth Annual Professional Achievement Award of the Section.

Section president D. S. Rosenberg (left) presents award to Prahl. Onlookers are: (l. to r.) G. C. Crewson, R. B. MacMullin, R. L. Murray, and M. E. Bretschger.

Prahl, inventor of the Raschig Phenol Process now in operation at Durex Plastics in North Tonawanda, and at Union Carbide, said that ridicule encountered by those with new ideas, discouragement in the face of adversity, and attraction by other interests, are most difficult to overcome. The roots of an invention lie as much in the moral as in the intellectual area of man. We are behind Russia in the development of the space program of the nation, he said, not as result of lack of intellect, but rather from lack of determination.

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Prahl illustrated his remarks by discussing the phenol process which began as an idea in 1928 and suffered much difficulty, setback and ridicule before it was finally operated successfully at Durex, in North Tonawanda, in 1941. In the case of the phenol process, as in other technical developments, the success of the process hinged mainly on patience and stubbornness in fighting for the realization of the goal.

Prahl, who holds a chemistry degree from Leipzig University and a doctorate from Heidelberg, came to this country when Durex bought the process from the Raschig Company of Germany in 1937, to direct design, construction, and operation of the local phenol process plant.

George E. Holbrook was presented with an Outstanding Achievement Award by the University of Michigan. A vice president of DuPont, and a director of the company, Holbrook is also a past president and director of A.I.Ch.E. A Michigan alumnus, he has three U. of Mich. degrees, having received his Ph D from the University in 1933. The Award, established in 1958 by the Regents of the University, honors outstanding alumni of the college for their achievements.

Holbrook started his career with Du Pont as a research chemist in the Jackson laboratory. He has been with the company ever since, holding positions of increased responsibility until he was appointed to the post of assistant director of the Development Department in 1951. He became vice president in 1958.

The University Citation reads in part: the University expresses its respect for the position to which he has attained, and its profoundest esteem for the solid abilities and responsible industry by which he has won that position, and its gratitude for the honor which he has thereby brought to his alma mater.

In addition to having held the position of president of the Institute in 1958, he was also presented with the A.I.Ch.E. Professional Progress Award in 1953 for his remarkable record as a chemical engineer, and his energetic public service in advancing the profession.

Presentation of the U. of Mich. award was made recently at a special ceremony during which three other graduates were also honored.

continued on page 130

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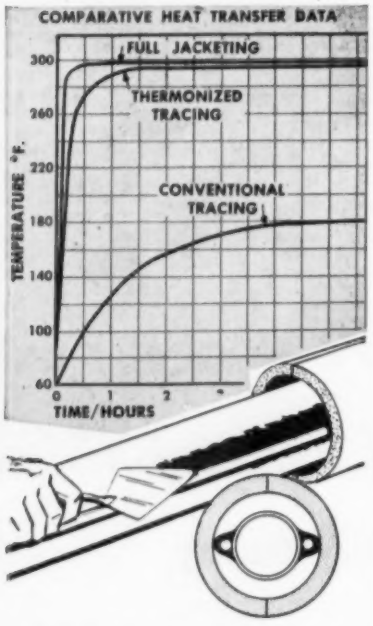

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people

from page 129

Best presentation awards to Hutchinson and Bondi

BEST PRESENTATION of paper awards at recent A.I.Ch.E national meetings went to **C. A. Hutchinson Jr.** and **A. A. Bondi.** Hutchinson was cited for his presentation at San Francisco, Bondi for his delivery at the St. Paul meeting.

Hutchinson is co-author, along with Philip H. Braun, of *Phase Relations of Miscible Displacement in Oil Recovery.* A member of the Research and Development Department at Atlantic Refining, Dallas, Texas, he has been with the company since 1949. At present, Hutchinson is supervisor of the reservoir mechanics group, but he has worked in various capacities including research in reservoir mechanics and engineering, and operations research and project evaluation. In addition to his training in chemical engineering, Hutchinson has a BS in electrical engineering. He was for several years on the faculty of the University of Colorado in the Applied Mathematics Department, and at the Engineering Experiment Station.

Bondi Hutchinson

Bondi's delivery of the paper, *A Corresponding States Correlation for Higher Molecular Weight Substances,* at the St. Paul meeting won him the

continued on page 134

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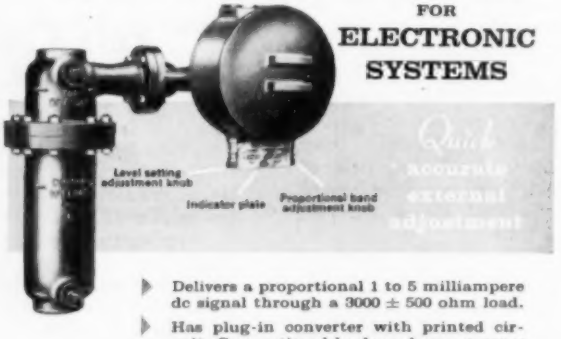

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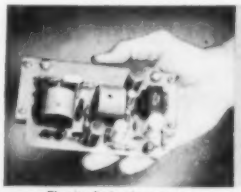
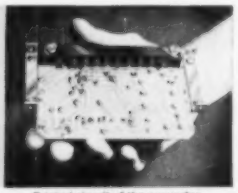

Plug-in electronic converter assembly.


Printed circuit of the converter assembly.

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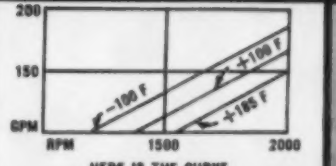

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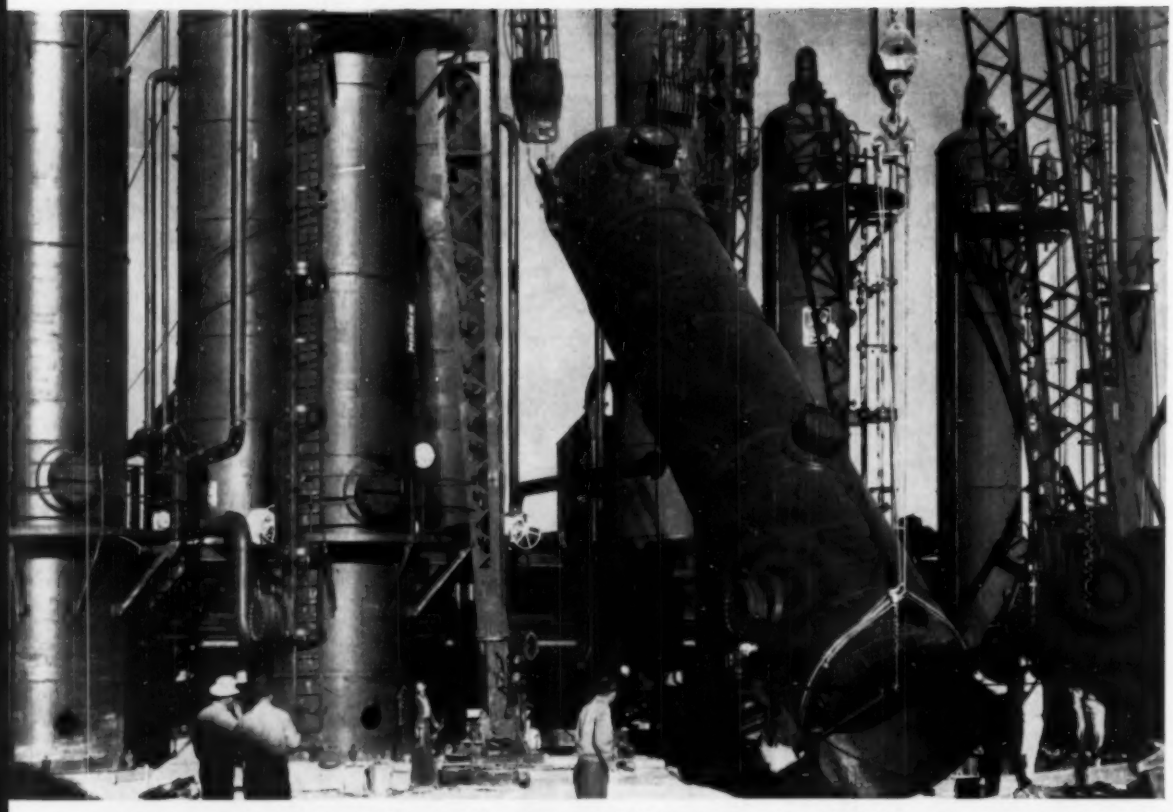
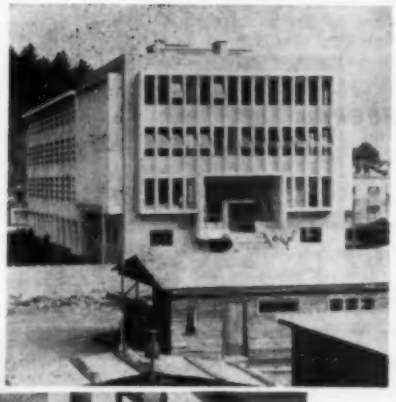
While fund-raising continues, actual construction gets underway on the United Engineering Center on United Nations Plaza in New York. Here are the first pictures of the excavation work going on. From this foundation the modern Center will rise 18 stories and be ready for occupancy by late 1961.

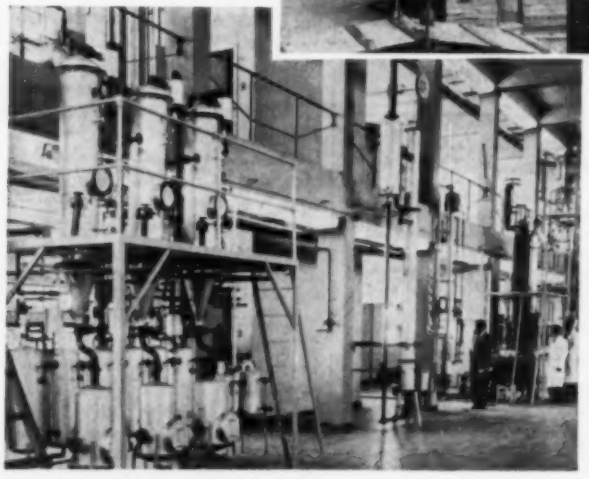


Three carbon dioxide absorbers being erected by Brown & Root for Transwestern Pipeline's gas treating plant near Fort Stockton, Texas. Each absorber weights 91 tons, is 84 inches in diameter, will operate at 1000 lb./sq. in.

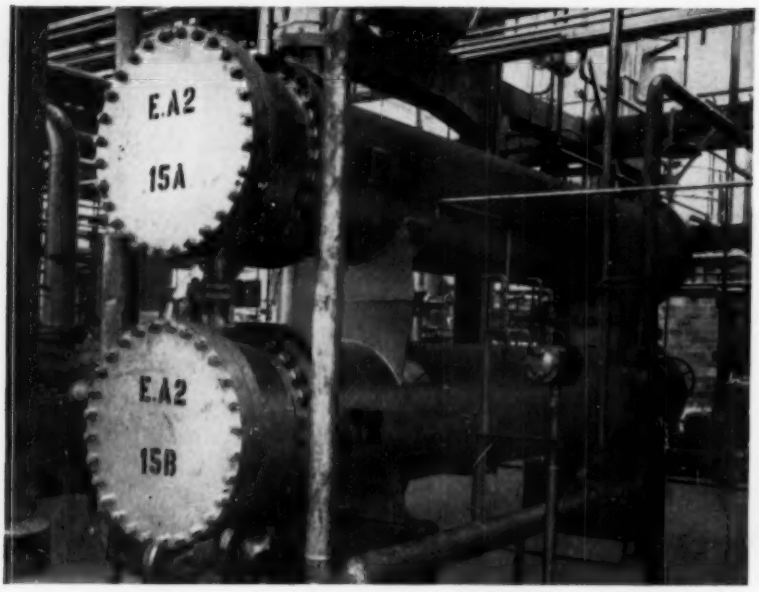
Computer designs computer! Circuit designs for the new IBM 7080 data processing system were prepared by its predecessor, the IBM 705 III.



The new Technological Research Institute being built at the University of Concepcion, Chile. (Below) The Unit Operations Lab in the new Institute.



Making use of the behavoir of metals near absolute zero, this golfball-sized sphere will spin freely for years as part of a new super-accurate gyroscope built by General Electric. Sphere will rotate in vacuum, supported by magnetic field.



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people

from page 130

citation. He co-authored the work with D. J. Simkin, also of Shell Development in Emeryville, California.

Bondi, who has also worked with Oil States Petroleum and River Petroleum, was educated in Germany. He is author of several books and articles, including *Physical Chemistry and Lubricating Oils*, and a contributor to the *Interscience Encyclopedia of Chemical Technology*, and the *Source Book of Rheology*.

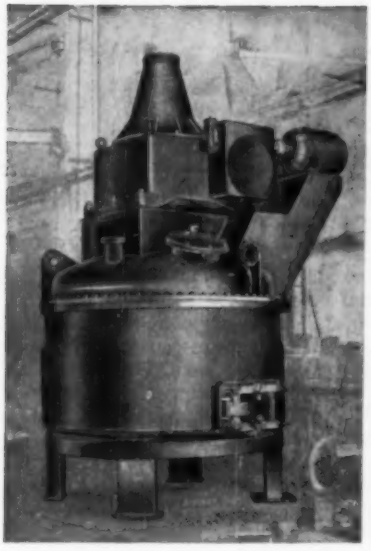
Stuart Nussbaum has joined the staff of *CEP* as associate editor-technical. A BS ChE from Newark College of Engineering, he is now doing graduate work at the same college. Nussbaum, in addition to considerable editorial experience, was for some time with the Air Force Cambridge Research Center, in the Research and Development Command. He has also done other work in industry, including solid state research at the RCA lab in Somerville, N. J., and in molecular sieves at Linde's Tonawanda plant.

S. D. Kirkpatrick has retired as editorial director of *Chemical Engineering* and *Chemical Week*, McGraw-Hill publications. He will continue as a consulting editor, as vice president of McGraw-Hill Book Company, and as director of several chemical firms. A former president of A.I.Ch.E. (1942) Kirkpatrick is the recipient of many honors, including the Institute's Founders Award.

W. Reed Wright, Jr. is a new employee of Allied Chemical. He recently joined the Development Department, Nitrogen Division at Hopewell, Virginia.

George E. Best has joined the Manufacturing Chemists' Association as staff secretary to MCA's committees on air and water pollution abatement and chemical packaging. He will also handle special assignments. Best, on the Air Pollution Abatement Committee from 1949 to 1955, was active in preparing MCA's publication, A Rational Approach to Air Pollution Legislation.

Wendell G. Fogg retired from Air Reduction Company recently, ending 41 years of service. For the last eleven years he has been executive engineer.



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For more information, circle No. 50

Robert Silva will head a systems engineering group at the Foxboro Company. Formerly associated with the company's Petroleum, Chemical and Power Division, Silva will be located at the Foxboro, Mass. main plant. The new group specializes in advanced application engineering phases of computer control in the process industries.

L. E. Swabb heads petroleum processes and applied mathematics. **M. M. Lambert** now heads the personnel and research effectiveness section, and **W. J. Porter, Jr.** is head of a chemicals section.

Hung-Hsin Lo appointed manager of the pilot plant of the Reheis Company, Berkeley Heights, N. J. Hung-Hsin was previously employed at Babcock & Wilcox, Chicago.

Abbott Byfield named administrative assistant to chairman of the board of Kimberly-Clark. Byfield has been with the company since 1939, except for a five year stint with the government in the Office of Scientific Research and Development. He was director of new products in corporate product planning.

MARKETING

Rudy P. Lowe takes over as director of Industrial Systems Sales for B-I-F Industries. Lowe, who has been associated with the Providence, R. I. firm since 1932, continues as president of the Proportioneers Division of the Company.

Jean F. Malone appointed sales development manager of plastic materials for B. F. Goodrich. A fourteen year veteran of the company, he will direct sales and technical activities connected with new plastic materials.

NECROLOGY

George R. Lyon, 58, manager of foreign synthetic rubber projects for Goodyear Tire and Rubber. A graduate of Ohio State, he served the company for over 30 years in both research and production positions.

Jesse H. Hubel, 70. Hubel was a member of the Development Department at Canadian Industries, Ltd. until his retirement in 1955.

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Communicating your convictions gains better understanding, improved relations, greater results for engineers

Breathes there a man with soul so dead, who never to his friend has said, "Don't those lamebrains in the Department every get ANYTHING right? . . . I very carefully wrote EVERYTHING down, very logically and clearly . . . didn't leave a thing out . . . and they still don't get my point!" — or words to that effect?

The only qualification you need for having voiced these sentiments is that you occupy yourself daily with one or more **people**, because it is with **people** that communications break down — people on either end of the chain of communication, whether they be employee or employer, buyer or seller, veteran or newcomer. **(See Footnote)**

Whether it be an internal or external message, verbal or written, a telephone message or a memorandum, a formal report or a business letter, technical or elementary, a progress report or a comparative, scientific analysis, the ground-rules are the same for successful communications.

Take our friend who is beset by "those lamebrains," for instance. Can he be so positive that it was the **other** end of the chain that bogged down? Perhaps he was **too complete** in his instructions, where simplicity would have sufficed. Perhaps the receiver merely needed short, concise directions, not the logical, careful rationalization of the writer. Perhaps his memorandum was clear to **him**, but maybe the "practical examples" he gave weren't so practical to the recipient because it was **outside his frame of reference**, background or experience. Maybe a telephone call would have been a more efficient medium of exchange in this instance.

The basic problem, then, is one of **needing** to transmit our beliefs, decisions, conclusions from us to someone else, and to have that other person **understand what we mean** — quickly, accurately, simply and — pleasantly.

Perhaps one of the cardinal rules for better communications, then, is **better understanding**: consideration for others, and a **desire** to understand another's viewpoint. Actually, this merely bespeaks the real origin of "fluid communications": **thought**, for thought plays a vital role in what we feel, observe, write, say, or demonstrate; and these **are** the principal means of communication available to everyone: thinking, feeling, observing, writing, saying, demonstrating. **(See Footnote)**

Does this sound like a monumental, life-long task? It is, and it isn't. It is **not** monumental unless you make it so by resenting it, and it is life-long, because as you change, as others change, as business changes, so do communication forms, vocabularies, meanings, frames of reference.

It is not sufficient in a competitive economy to **have** convictions; it is necessary to **sell** your convictions to someone who can either do something with them, or authorize you to do so. This, then is one of the chief values of communications: to help you accomplish your aims in engineering, in your professional life, more quickly, more productively, more successfully. Combined with your technical knowledge, your ability to perform and deliver, and your initative, communications can become the most valuable tool in your professional "workshop."

FOOTNOTE: For more detailed information on this subject, write for "Fluid, Fluent Communications," to WESTERN SUPPLY COMPANY, HEAT EXCHANGER DIVISION, P. O. BOX 1888, TULSA, OKLA. — and if there's a heat exchanger in your company's future, we'd appreciate a "line of communication" from you!

For more information, circle No. 46

SAVE THOSE BACK ISSUES!

Every so often an unprecedented demand for a particular issue, or an unexpected influx of new subscribers and members puts the editor in the embarrassing position of running out of copies of Chemical Engineering Progress. This has happened several times in our short history and if members have copies of any of the following issues, we would be glad to purchase them.

The issues which we need and for which we will pay 75 cents each are: January, April and December 1959.

All these issues were overprinted to the usual extent, but because popular features spurred single copy sales, our reserves are exhausted.

Help fellow members by sending your back numbers of the issues specified above to:

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local sections

Computers, separation techniques, highlight New York one-day

WHAT ROLE ARE COMPUTERS going to play in process control? This question, the subject of much controversy in engineering circles, was brought into sharp focus at the All-Day Technical Symposium of the New York Section (*Clem Labine*) held in October.

What's to be gained from computer control, the session chaired by L. E. Slater, Foundation for Instrumentation Education and Research, covered the subject from the very beginning: *What is computer control?*, H. R. Karp, Control Engineering. It also presented three separate viewpoints: the computer manufacturer's, M. Phister; the control engineer's, C. D. Close, Compudyne Control; and the chemical engineer's, R. Hall, Du Pont. (Hall's paper appears on page 62).

A panel made up of the speakers, discussed *What's to be Done to Effect Computer Control*. The problem of cost, said Phister, will be solved as new design techniques are developed and volume increases, bringing costs down. While some members expressed concern over obsolescence, particularly with costs so high, Hall said that the Univac makes money hand over fist for his company, and it was obsolete when they got it!

Running concurrently with the meeting on computers, was another session on new developments in separation techniques. Three papers were presented on processes, developments, and performance-cost evaluation of distillation trays. In another panel a group of industrial experts took up the problems that may arise between customer and contractor.

General chairman of the symposium was H. I. Wolff. The panel on separation techniques was headed by C. M. Thatcher, Pratt Institute. Moderator of the computer control panel was T. J. Williams, Monsanto.

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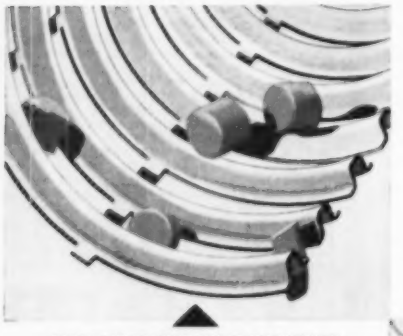

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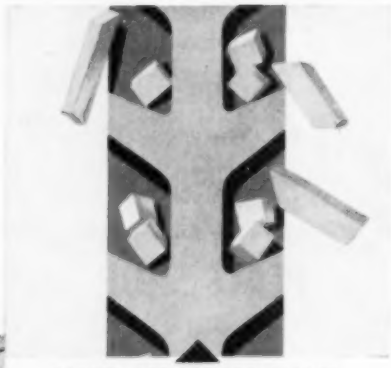

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For more information, turn to Data Service card, circle No. 76

Obsolete?

Is your technical knowledge obsolete? There is a good chance the answer is yes if you completed your formal schooling more than five years ago. This challenging statement was made by Gordon C. Williams, head of the Chemical Engineering Department, University of Louisville. Occasion was the **Louisville Section** (*Joseph E. Mosel*) November meeting.

A committee of the American Society of Engineering Education pointed out in 1952 that industry wanted more emphasis on theoretical training in undergraduate curriculums. As a result, colleges and universities are spending more time on the fundamentals of physics, chemistry and mathematics. This trend is bringing other branches of engineering closer to chemical engineering. Concurrently, in our field the empirical approach to unit operations is disappearing.

A look at the undergraduate curriculum in a current university catalogue, Williams suggested, would hold many surprises. He recommended night courses at the graduate level as one method of up-dating our engineering information.

Who owns technical know-how?

No person or industry can hold an exclusive mortgage over the thoughts and mental products of any person, Stanley Bilker told the **Philadelphia-Wilmington Section** (*D. B. Creath*) in November. The Philadelphia patent specialist said, however, an employer does own that technical knowledge which an employee has conceived, produced, or obtained as part of his job. Technical know-how was defined as the knowledge contained in trade secrets, devices, patterns, secret processes, patents, and copyrights which give an enterprise a competitive advantage in our society. The employee is bound by implication or, as is generally the case in industry today, by an expressed contract to keep in confidence these trade secrets. Even though the mental products of an individual are his inalienable property, an employer may contract for the creativity of a person's mind in a specific endeavour by giving the creator a fair and acceptable compensation. This trade knowledge contract includes all patentable and non-patentable knowledge. Achievements not related to and acquired outside of one's field of employment are not covered by this technical know-how contract. Trade secret knowledge is usable if independently acquired but unusable

continued on page 138

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local sections

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if in violation of a trust between an employee and employer.

In several cases, involving the misappropriation of a company's technical know-how by former employees, the decisions upheld the employers nondisclosure rights where a breach of confidence had been made by the former employee. In one case, where this knowledge was independently acquired, the former employee retained his right to use this trade knowledge.

News from California

Developments in the rapidly expanding field of computer technology were outlined by S. L. Jamison, to the **Northern California Section** (*W. B. Hauserman*) in October. Jamison, University and Research Representative, IBM, described Stretch, the computer system developed through joint efforts of IBM and AEC.

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Southern California departed from the chemical engineering theme, with Government monetary policy, and the Federal Reserve System the subject under discussion at the Section (*R. D. Sheeline*) meeting in October. David Snell, assistant professor of finance at the UCLA Graduate School of Business Administration, told the members that the Federal Reserve Bank does not have the power to regulate consumer down payments as a control on credit, and is considerably worried over this. In 1955, it asked Congress to grant this control and was refused. This may be one reason, the Bank feels, that the 1957 recession was so serious.

Tennessee Valley All-Day Meeting

Various aspects of the chemical engi-

continued on page 140

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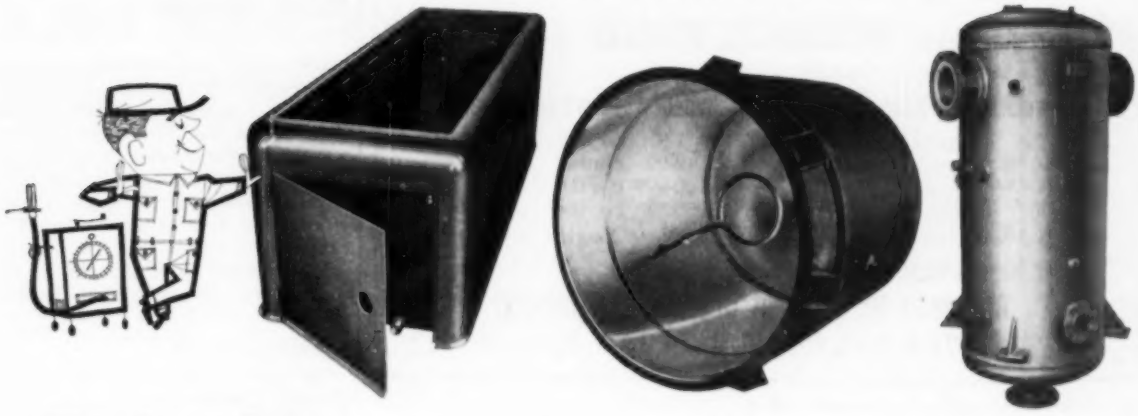

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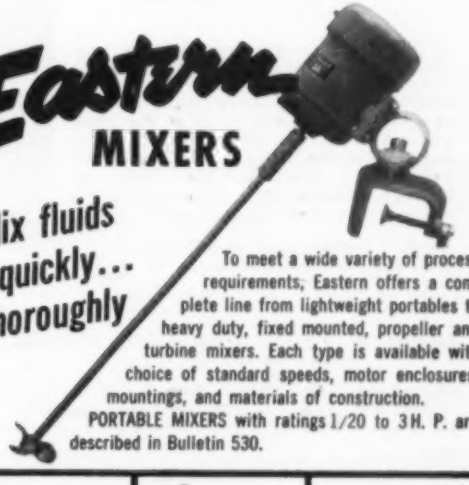

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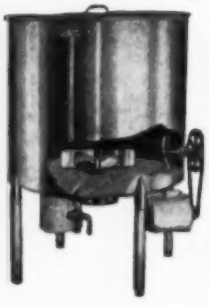

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local sections

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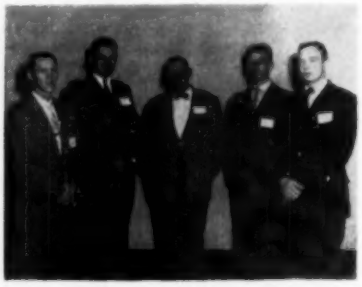
neering field were touched on at the **Tennessee Valley Section** (*Lindsay A. Allen, Jr.*) Symposium in November. The Second Annual All-Day Meeting was highlighted by a discussion of Statistical Techniques in Process Control, delivered by R. M. Milner, Chemstrand, and Some Elements in Solid Propellant Technology, J. W. Parrott, Rohm & Haas. J. P. Coffin chaired the eight-paper meeting, held at Decatur, Alabama.

Student chapters

At the annual regional meeting of Student Chapters (*R. H. Luebbers*), held last fall at the University of



J. J. Healy (center), A.I.Ch.E. vice president, greets student prizewinners at Missouri meeting.

Missouri, James E. Gagliardo, University of Missouri, was awarded First Prize for his paper on Design of a Sodium Hypochlorite Plant. The all-day session was attended by students from half a dozen area colleges.

Also meeting

An industrial chemist turned journalist, Ed Danforth, addressed the **Atlanta Section** (*Leonard M. Wylie*) in December. Danforth is a former sports editor of the Atlanta Journal . . . The Atlanta Section heard John E. Bing in November, on Professionalism and Registration. Registration, he said, is a public declaration of competence which acknowledges the responsibility of a person to himself and society . . . Investing for technical men was Charles O. Brown's subject at the **Maryland Section** (*Philip Messina*) in December . . . A combined leadership of engineers and community officials is necessary to provide long range planning necessary to attract new industry to the region, the **Northern West Virginia Section** (*W. H. Holstein*) was told in October. W. H. Myers, executive manager of the Upper Ohio Valley Development Council was the speaker . . . A briefing on the latest developments in fluid mixing technology went to the **East Tennessee**

continued on page 142

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local sections

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Section (*James E. Williams*). J. Y. Oldshue was the speaker . . . The importance of patents, copyrights, and trademarks was the subject of G. W. Shaw's talk to the **Rochester Section** (*Robert L. Cramer*) in December . . . Gas-cooled reactors have significant advantages over water cooled, Robert A. Charpie, assistant director, Oak Ridge Lab, told the **Pittsburgh Section** (*G. J. Haddad*) in December. Occasion was a joint session with the American Nuclear Society . . . Donald L. Katz, aired his views on Advanced training in engineering at the **New York Section** in November.

Xanthate production will begin in Mexico when a plant at Morelia goes on stream early this year. The Stauffer affiliate, Industrias Quimicas de Mexico, S. A., will locate the project next to its main carbon disulphide production center. Output is designed to supply the Mexican mining industry need for xanthate floatation agents.

All standard grades of sulfuric acid will be manufactured by Du Pont at its new unit, to be ready in about a year at the Houston works. The multi-million dollar unit will supply acid for the company's caprolactam plant now under construction at Beaumont. It will also provide an additional source of supply for the petroleum and chemical industry in the Gulf coast area. The new plant will have facilities for reclaiming acid used in the manufacture of high octane gasoline, thus assisting the oil industry with this disposal problem.

The new biological processing plant of Quimica Reheis do Brasil has gone on stream. The Reheis subsidiary will supplement a like operation in Uruguay which provides liver fractions, bile salts and pancreatic substances that are eventually refined in the company's Stamford, Connecticut, plant. It is expected to double company capacity to produce liver and pancreatic extracts.

A German company for the manufacture and sale of titanium dioxide pigments just formed by Du Pont and Sachtleben A. G. of Cologne, will be 75 percent owned by the German firm. The company, Pigment-Chemie G.m.b.H., will supply titanium dioxide pigments primarily for the paint, paper, plastics, and rubber industries in Western Europe. Annual capacity is designed for 40 million pounds.

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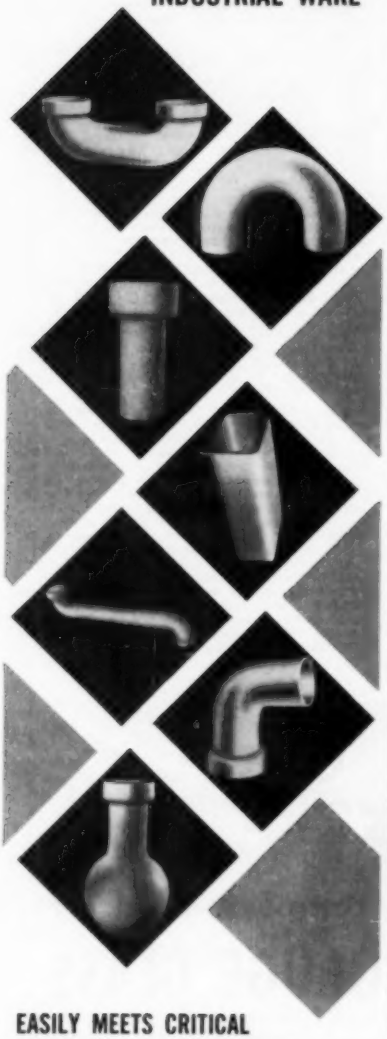

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1960—MEETINGS—A.I.Ch.E.

● Atlanta, Ga., Feb. 21-24, 1960. Hotel Atlanta Biltmore. **A.I.Ch.E. National Meeting.**

● Mexico City, Mex. June 19-22, 1960. Hotel Del Prado. **Joint Meeting with Instituto Mexicano de Inginieros Quimicos** — Tech. Prog. Chmn.: G. E. Montes, Northern Nat. Gas Co., 2223 Dodge St., Omaha 1, Nebr. **Petroleum & Natural Gas Processing in Latin America**—F. W. Jessen, Petrol. Eng. Dept., U. of Texas Austin, Tex. & F. Corcuera, Ref. Madero, Tamps, Mex. **Chem. Engineering in Latin America**—G. Mayurnik, W. R. Grace, 3 Hanover, Sq., New York 4, N. Y. & S. Vasan, Chem. Constr. Corp., 525 W. 43 St., New York 36, N. Y. **Chemical Engineering Education in the Americas**—W. R. Marshall, Jr., Dean, U. of Wisconsin, Madison 6, Wisc. & F. G. Roel, Inst. Tec. y de Estudios Sup. Sucursal de Corres J. Monterey, Nuevo Leon. **Machine Computation-Optimization, Pitfalls, and Potentials**—W. M. Carlson, Louviers Bldg., Dupont, Wilmington 98, Del. **Distillation Equipment**—R. Katzen, 3732 Dogwood Lane, Cincinnati, O. & F. Ocampo, PEMEX, Vallarta #7-4° Piso, Mex., D. F. **Minerals and Metals**—D. B. Coghlan, Foote Mineral Co., Box 576, Berwyn, Pa. **Transfer Processes in Two-Phase Systems**—S. G. Bankoff, Ch.E. Dept., Northwestern U., Evanston, Ill. & A. Hoyos, Xola #1253-2° Piso, Mex., D. F. **Construction and Operating Costs for Latin American Projects**—R. Voorhees, Union Carbide Dev. Co., 30 E. 42 St., N. Y. 17, N. Y. & R. Pardo, Dir. Bufete Ind., Insurgentes sur 132-102, Mex., D. F. **Laboratory and Pilot Plant Techniques**—J. T. Cumming, Penn College, Cleveland 15, O. & M. Puebla, Inst. Mex. de Invest. Tec., Calzada Legaria #694, Mex., D. H. **Cryogenic Engineering**—F. Kurata, Ch.E. Dept., U. of Kansas, Lawrence, Kan. **Selected Papers**—J. A. Samaniego, Shell Dev. Co., Emeryville 3, Calif. **Financing International Projects**—P. F. Genachte, Chase-Manhattan Bank, New York, N. Y. & J. Horcasitas, Credito Bursatil, Isabel la Catolica #38, Mex., D. F. **Student Program**—J. J. McKetta, Ch.E. Dept., U. of Texas, Austin, Tex.

● Moscow, USSR, June, 1960, 1st Congress of International Fed., Automatic Control. To cover areas of **Theory, Hardware & Applications of Automatic Control.** U. S. participation sponsored by American Automatic Control Council, Affiliated societies: **A.I.Ch.E., ASME, AIEE, IRE, ISA.** A.I.Ch.E. Chmn.: D. M. Boyd, Universal Oil Prods., Des Plaines, Ill. For attendance & deadline info write: Secy., W. E. Vannah "Control Engrs.", 330 W. 42 St., N. Y. 36, N. Y.

● Buffalo, N. Y., Aug. 14-17, 1960, Statler Hilton Hotel. **4th National Heat Transfer Conference & Exhibit. Sponsored by A.I.Ch.E. & ASME.** A.I.Ch.E. papers to S. W. Churchill, U. of Mich., Ann Arbor, Mich. ASME papers to J. P. Hartnett, U. of Minnesota, Minneapolis, Minn. Exhibit info to P. A. Joculvar, A.I.Ch.E., 25 West 45 St., N. Y. 36, N. Y.

● Boston, Mass. Sept. 7-9, 1960. M.I.T. **Joint Automatic Control Conference.** Sponsored by A.I.Ch.E., AIEE, IRE, ASME. For A.I.Ch.E. info refer to: W. H. Abraham, Eng. Exp. Sta., Dupont, Wilmington, 98, Del.

● Tulsa, Okla., Sept. 25-28, 1960, Hotel Mayo. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. **Multiphase Flow in the Production & Drilling of Oil Wells**—L. P. Whorton, Atlantic Refining, Box 2819, Dallas 1, Texas. **Natural Gas & Natural Gas Liquids**—R. L. Huntington, U. of Oklahoma, Norman, Okla. **Advances in Refinery Technology**—W. C. Offutt, Gulf R&D Co., P. O. Drawer 2038, Pittsburgh 30, Pa. **Petrochemicals**—C. V. Foster, Continental Oil Co., Ponca City, Okla. & H. L. Hays, Phillips Chem. Co., Bartlesville, Okla. **Piloting, or Why Buy the Restaurant When All You Need is a Meal**—R. E. Weis, Phillips Pet. Co., Bartlesville, Okla. & D. Popovac, Continental Oil Co., Ponca City, Okla. **Corrosion & Materials of Construction**—

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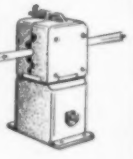

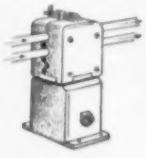

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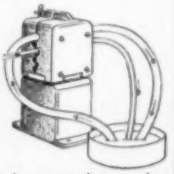

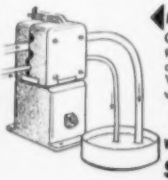

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Deadline for papers: May 2, 1960.

● Washington, D.C., Dec. 4-7, 1960. Statler Hotel. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: D. O. Myatt, Science Communication, Inc., 1079 Wisconsin Ave., N.W., Wash. 7, D.C. **Air Pollution**—A. J. Teller, U. of Florida, Gainesville, Fla. **Unsteady—State Instrumentation**—T. J. Williams, Monsanto, Chem. Co., St. Louis, Mo. **Fluid Dynamics**—A. C. Acrivos, U. of California, Berkeley, Calif. **Information & Communications**—D. E. Gray, NSF, Wash. D.C. **Nuclear Reactor Operations**—R. L. Cummings, Atomics International, Canoga Park, Calif. **Nuclear Chemical Plant Safety**—C. E. Dryden, Ohio State U., Columbus, O. **Phase Transitions**—G. Bankoff, Northwestern U., Evanston, Ill. **Selling Abroad**—J. Costigan, The Sharples Corp., 501 Fifth Ave., New York 17, N. Y. **Chemical Engineering—A Vital Link in Broadening the Uses of Agricultural Crops**—J. E. Simpson, U.S.D.A., Wash., D.C. **Chemical Warfare—Controlled Production of Aerosols**—L. E. Garono, Army Chem. Corps. **Role of the Chemical Engineer in Environmental Health Engineering**—W. L. Faith, Air Pollution Foundation, 2556 Mission St., San Marino, Calif. **Servicing the Foot Soldier: 1. Feeding 2. Clothing 3. Protection**—Leo Sano, Quartermaster R&Eng. Command, Natick, Mass. **Phenomena Affecting Materials in Extreme Environments**, J. Hearne, Air Force R&Eng. **Effects of Government Programs on Chemical Engineering Education**—No Chmn. Appointed. **Chemical Engineering of Solid Propellant Production**—No Chmn. Appointed. **Pilot Plants**—No Chmn. Appointed. **Direction of Large Technical Programs**—No Chmn. Appointed.
Deadline for papers: July 5, 1960:

1960—MEETINGS—NON-A.I.Ch.E.

● Toronto, Canada, Feb. 18, 1960. Montreal, Canada, Feb. 19, 1960. **The Chemical Institute of Canada.** Protective Coatings Division Conference.

● Chicago, Ill. Mar. 29-31, 1960. Hotel Sherman. **22nd Annual American Power Conference.** Sponsored by Illinois Institute of Technology, many colleges, universities, and professional societies.

1961—MEETINGS—A.I.Ch.E.

● New Orleans, La., Feb. 26-Mar. 1, 1961. Hotel Roosevelt. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: H. L. Malakoff, Petroleum Chem. P.O. Box 6, New Orleans 6, La. **Kinetics of Catalytic Reaction; Brainstorming Technical Problems; Petrochemicals—Future of the Industry on Gulf Coast; Centrifugation; Future Processing Technologies in the Petroleum Industry; Education and Professionalism; Mathmatics in Chemical Engineering; Evaluation of R&D Projects; Liquid—Liquid Extractions; New Processes in the Area; Water from Sea Water; Materials of Construction; Flow Through Porous Media.**
Deadline for papers: Sept. 5, 1960.

● Cleveland, O., May 7-10, 1961. Sheraton-Cleveland. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 10, O. **Management Criteria for Capital Investment; Technical Phases of the Synthesis of Isoprene; Process Development of the New Synthetic Rubbers; Use of Radioactive Materials for Chemical Process Control; Modernized Processes for Heavy Chemical Manufacture; Optimum Utilization of Pilot Plant Facilities; Petrochemicals as The Starting Materials for High Polymers;**

continued on page 147

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from page 45

Chemical Engineering and Metal Refining; Fluid Mechanics; Applications of Photography in Chemical Engineering.
Deadline for papers: Dec. 7, 1960.

• Lake Placid, N. Y., Sept. 24-27, 1961. Lake Placid Club. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: E. R. Smoley, 30 School Lane, Scarsdale, N. Y. **Process Management; Commercial Chemical Development; Sales Engineering.**

• New York, N. Y., Dec. 3-6, 1961. Hotel New Yorker. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: A. V. Caselli, Shell Chem Corp., 50 W. 50 St., N. Y. 20. N. Y. **Heat Transfer; Management; New Processes; Nuclear Engineering; Water Pollution; Process Dynamics; Pilot Plants; Fundamentals; Petroleum & Petrochemicals; Fluids; Fluidization; Sublimation; Adsorption; Student Program.**

1962—MEETINGS—A.I.Ch.E.

• Los Angeles, Calif., Feb. 4-7, 1962. Hotel Statler. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: G. C. Szego, Space Technology Labs, Inc., P.O. Box 95.001, Los Angeles 45, Calif.

• Baltimore, Md., May 20-23, 1962. Lord Baltimore Hotel. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: G. L. Bridger, R&D Div., Washington Research Center, W. R. Grace, Clarkesville, Md.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

Computers in Optimum Design of Process Equipment—Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.

Solar Energy Research—J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.

Hydrometallurgy—Chemistry of Solvent Extraction: G. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbus, Mo.

Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

Drying—R. E. Peck, Ill. Inst. of Tech., 330 So. Federal, Chicago, Ill.

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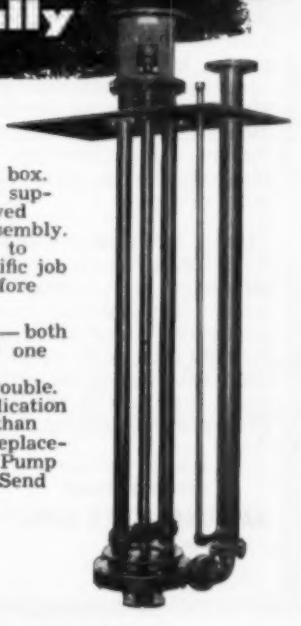

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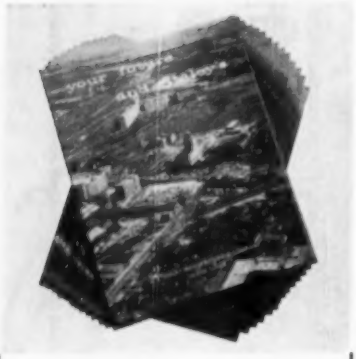

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CHEMICAL ENGINEER—P.E., B.S., 1948. Eleven years' experience in design, construction, operation and sales in the process industries. Desire agency or representative status with process equipment manufacturer requiring technical sales and service. Gulf Coast or California preferred. Resume available. Box 13-2.

CHEMICAL ENGINEER—B.S.Ch.E. Fourteen years' experience process design and development, production and liaison engineering in the chemical and pharmaceutical industry. Seek challenging position in process engineering or plant engineering with chemical manufacturer. Box 14-2.

CHEMICAL ENGINEER—B.Ch.E., 1951, P.E., age 32; four and one half years' plant engineering in heavy inorganic chemicals, four years' project engineering in high pressure urea plants. Desire challenging position utilizing experience or allied processes. Box 16-2.

CHEMICAL ENGINEERING UNIVERSITY PROFESSOR—ten years' of university research, teaching, and administration. Honors, publications. Seek new challenging twelve month university position. Available: Summer—1960. Box 17-2.

(continued on page 150)

An Invitation To Join ORO...Pioneer In Operations Research

Operations Research is a young science, earning recognition rapidly as a significant aid to decision-making. It employs the services of mathematicians, physicists, economists, engineers, political scientists, psychologists, and others working on teams to synthesize all phases of a problem.

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For further information write:
Professional Appointments

OPERATIONS RESEARCH OFFICE
ORO The Johns Hopkins University
6935 ARLINGTON ROAD
BETHESDA 14, MARYLAND

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MECHANICAL ENGINEERS
CHEMISTS

We have a number of unusually attractive opportunities in both the production and the research and development fields for technical men of proven ability.

PROCESS DEVELOPMENT

These positions are in the fields of intermediates, nylon fibers and plastics. Complete pilot plant facilities are available, and the work offers real challenge and opportunity for personal growth.

We would prefer men with advanced degrees in Chemistry, Chemical Engineering or Mechanical Engineering for these positions.

There are also several openings for men in the research and analytical fields.

PRODUCTION ENGINEERING

These positions are in a continuous process chemical plant or a yarn spinning plant.

We are seeking men with technical degrees and several years experience in Production Engineering.

Since the men selected will have opportunities for growth into supervisory positions, we are interested in candidates who have both a capacity for and interest in supervision.

There are also openings in the production department for INSTRUMENT ENGINEERS, MAINTENANCE ENGINEERS and INDUSTRIAL ENGINNERS.

Excellent Salary and
Liberal Benefit Arrangements

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W. M. JOLLY, Supervisor of Personnel

NATIONAL ANILINE DIVISION

P. O. Box 831, HOPEWELL, VA.

Allied Chemical

CHEMICAL ENGINEER

Young man to work with belt research and development. World's largest V-Belt manufacturer. New manufacturing plant in Springfield, Missouri. Outstanding training program in Dayton, Ohio. Exceptional advancement opportunities. Company paid benefits. Excellent Salary.

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Personnel Supervisor

THE DAYTON RUBBER CO.
2342 West Riverview Ave.,
Dayton, Ohio

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Employment in
SAN FRANCISCO,

Position exists for experienced project engineer capable of assuming supervisory responsibility on design of major processing units.

Liberal relocation allowance for you and your family.

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GEORGE I. COPELAND,
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BECHTEL
CORPORATION
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To function at management level in establishing new, sizable LPG organization. Age to 45. Position requires considerable experience in marketing, including short- and long-term wholesale contract negotiations and administration. Must have experience in assessing market potentials and some experience in storage and transportation. Retail experience desirable. Salary commensurate with ability and experience. Send resume including background, training and experience. All replies will be held in strictest confidence.

Box 40-2

Ph.D or M.S. chemistry or metallurgy to train for research director. Small, excellent technical group. New facilities being installed to expand product development and sales service. Midwest location. Please send details education and experience. Box 3-2.

SITUATIONS WANTED
A.I.Ch.E. Members

(continued from page 149)

TECHNICAL WRITER—B.Ch.E., 1952. Desire technical and/or general writing assignments. Oklahoma City-Tulsa area. Three years' marketing (instrumentation), two years' process engineering (oil, overseas), two years' free lance writer. Box 18-2.

M.Ch.E. 1951—P.E. with fifteen years' research, process development, pilot plant, plant engineering production and process design experience. Project management. Plastics, polymers, coatings, organic chemicals. Desire position where capability and versatility count. N. Y. City. $10,000 minimum. Box 19-2.

B.S.Ch.E.—completed graduate studies. Tau Beta Pi, age 38, family, veteran. Nine years' experience production, R&D, process evaluation and control, process improvement, equipment design, pilot plant supervision. Prefer Maryland, Delaware area. Box 20-2.

CHEMICAL ENGINEER—M.S. Thirteen years' diversified experience in process and production control, assistant plant manager, process design, plant start-up and trouble shooting in chloro-alkali industry. Desire responsible position in production or development. Box 21-2.

CHEMICAL ENGINEER—B.S.Ch.E., 1958. Age 28, married, veteran. Chemical plant inspector for insurance company. Desire a position as a development, production or safety engineer. Prefer New England or New York location. Box 22-2.

BUSINESS-DIRECTED CHEMICAL ENGINEER—M.Ch.E., P.E., age 33. Will trade eight years' of diverse experience in research, production, process development and improvement, and economic evaluation for an opportunity in the management area. Good general business knowledge (special business courses) and strong report-writing ability. $10,500. Box 23-2.

ASSISTANT CHIEF ENGINEER

For the right man, an opportunity to put into practice both administrative and technical ability in supervision of large engineering projects.

Prefer M.S.Ch.E. Minimum of 5 years in administration and operations of engineering programs. Minimum of 3 years in supervision of graduate engineers.

Outstanding, rapid-growing company in field of solid propellants located in East Texas.

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PERSONNEL DEPARTMENT

THIOKOL CHEMICAL CORP.

Marshall, Texas

PRODUCT ENGINEER

Leading Coated Abrasives manufacturer has challenging opening for chemical engineer or equivalent with experience in coated abrasives applications in furniture manufacture and/or allied woodworking fields. Both plant and field responsibilities, including product design and field sales engineering, calling on woodworking manufacturers and assisting in solution of customers coated abrasive needs.

$6500-$7,000 to start. Opportunity for advancement for right person. Reply Box No. 1-2.

CHEMICAL ENGINEER—B.Ch.E. One and a half years' experience in design, nuclear power plants. Box 24-2.

CHEMICAL ENGINEER—desire summer employment with small company in New York-New Jersey area. S.B. degree, Master of Science in Chemical Engineering Practice from M.I.T., two years' new product development experience with major company, and one years' education at Harvard Business School will be at your disposal. Naturally, employment in June, 1961, can result from a mutually satisfactory summer. Box 25-2.

CHEMICAL ENGINEER—M.S.Ch.E. Fifteen years' experience in petroleum refinery technical service, manufacturing and process design. Four years' process design supervisor. Desire position supervising process design, Research and Development. Box 26-2.

SENIOR ENGINEER—Age 45. P.E. Twenty diversified years' design, project, automatic control, plant erection, start-up, foreign work, contracts on petro-chemical plants. Seek challenging staff or consulting position. Northeast, north central or foreign. $15,000. Box 27-2.

CHEMICAL ENGINEER—B.S.Ch.E., 1952. Age 29, single. Experienced in process engineering, economic studies and electronic computer program development and use. Imaginative and capable of making decisions and assuming responsibility. Desire challenging position with growing company. Box 28-2.

continued on page 156

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A new division has been established by IBM to develop advanced concepts and techniques in the design and application of computer systems for new fields. This new division represents an interesting opportunity to work with newly developed technologies. The entire division is engineer-oriented; its sole purpose is to develop new systems and services to be marketed in several years by IBM. One area of immediate interest is the achievement of advanced systems and concepts for the automatic control of industrial processes of all types.

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Knowledge and skill is required in two or more of the following areas:

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Qualifications: Advanced degree in Science, Engineering, or Mathematics and related experience . . . plus the ability to work well with a wide variety of industrial personnel. To extend your present abilities, training in process control and computer application will be available.

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Please write, outlining your qualifications and experience, to:
Mr. T. E. Burns, Dept. 534N, IBM Corporation
Advanced Systems Development Division
Poughkeepsie, New York

FEB. 21-27 1960

OPERATIONS RESEARCH

Operations Research in the Chemical Industry?

Of course! An excellent opportunity currently exists in the Production Planning Department of Monsanto Chemical Company's Organic Division. Position requires a working knowledge of operations research techniques, probability theory and mathematics through differential equations. Work will involve the development and implementation of solutions to complex business problems. A Master's degree in operations reseach with several years' experience in the chemical industry desirable. Salary commensurate with background and experience. All replies confidential.

Please send resume to:

Manager, Technical Employment

MONSANTO CHEMICAL COMPANY

Organic Division

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PHYSICAL CHEMIST—PhD

The U.S. Navy offers an excellent position for a physical chemist—PhD, with experimental ability and training in kinetics and thermodynamics, to head a group studying solid rocket propellant ignition and combustion.

The position is in the Career Civil Service and will be filled in accordance with applicable Civil Service procedures.

All inquiries should be directed to the Employment Officer.

NOL

U.S. Naval Ordnance Laboratory

White Oak

Silver Spring, Maryland

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Send resume and salary required to Box 41-2.

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IF YOU HAVE a B.S. in Chemistry or Chemical Engineering and 5 or more years production experience in the chemical industry in a continuous process operation, preferably with a supervisory background, we may have just the spot you are seeking in BUFFALO, N. Y. or Hopewell, VA.

This is an INTERESTING OPPORTUNITY with GROWTH POTENTIAL.

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Chemical Engineer with administrative ability to handle interplant technical correlations. Plan and direct experimental research problems in our East Texas plant.

Send detailed resume to:

PERSONNEL DEPARTMENT

THIOKOL CHEMICAL CORP.

Marshall, Texas

The Dow Chemical Company Western Division, Pittsburg, California (San Francisco Bay Area) has openings in its Engineering Department for graduate Chemical Engineers B.S. M.S., or Ph.D. Current openings include:

SENIOR PROCESS ENGINEER—Major work in new process design, evaluation and project administration. 5 to 12 years experience in chemical process or refinery with substantial design responsibility required.

PROCESS ENGINEER—Process design work of substantial scope for plant modification and new construction. Recent graduates with 0-3 years experience in chemical plant or refinery design desired.

Salary commensurate with background and experience.

Send resume to:

Ind. Relations,
THE DOW CHEMICAL CO.,
P. O. Box 351,
Pittsburg, California

ENGINEERING SOCIETIES PERSONNEL SERVICE, INC.

(Agency)

New York	Chicago	San Francisco
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These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the national societies of Chemical, Civil, Electrical, Mechanical, Mining, Metallurgical and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee agreement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

A weekly bulletin of engineering positions open is available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for non-members, payable in advance.

Positions Available
New York Office

DEVELOPMENT ENGINEER, graduate physicist, electrical or chemical engineer with extensive experience in solid state field with special emphasis on areas of semi-conductors, transistors, rectifiers, etc., for a company which manufactures and designs transformers, reactors, filters and windings for the electronic industry. Will give consideration to an applicant on a consulting basis. Agency fees, relocation expenses, etc. open to negotiation. Location, upstate N. Y. W8478.

CHEMICAL ENGINEER OR PHYSICIST with nuclear power experience. Salary, $6000-$12,000 a year. Location, western Pennsylvania. W8471(b).

MECHANICAL OR CHEMICAL ENGINEER, B.S. or M.S., with a minimum of five years' proven ability as a project manager. Must be capable of demonstrating a high degree of technical competence in areas related to complex industrial process design and control systems. Will have complete project responsibility for development of test facilities for aircraft and missile systems, sub-systems and components. Salary open. Location, Connecticut. W8452(a).

RESEARCH PROCESS ENGINEER, degree in chemical engineering; will consider man with from none to ten years' experience, for company manufacturing cellulose. Location, New Jersey. W8416.

JUNIOR PROCESS ENGINEER, graduate chemical engineer, with experience, to assure production quality, maintain production specifications, investigate customer complaints and general implementing of transfer of new products from research, development to production. Company manufactures industrial plastics. Salary, $6000-$6500 a year. Company pays placement fee. Location, Delaware. W8405.

CHIEF ENGINEER, mechanical or chemical graduate, with ten years' experience in chemical process equipment design and application, i.e. liquid agitators, blenders, ball mills, pressure vessels, etc. Salary high. Location, Ohio. W8398.

ENGINEERS. (b) Chemical Engineer or Ceramics Engineer, to assist head of department in the production, formulation and control of glazing. Will consider a recent graduate. Salary, to $8400 a year. (c) Research and Development Engineer, chemical or mechanical graduate, to work on R & D for above processes. Some knowledge of statistical quality control methods desirable. Salary, to $8400 a year. Location, western Pennsylvania. W8364.

PROCESS ENGINEER, graduate chemical, 28-50, with a minimum of five years' experience in plant design and process evaluation in gas treating and low temperature processes. Salary, $8000-$10,000 a year. Location, Midwest. W8346.

PRODUCT MANAGER, degree in mechanical or chemical engineering, but possibly in forestry, with about five years' experience to include a wide acquaintance among people in the lumbering, saw mill and wood working trades. Selling experience such as with a manufacturer of equipment used by these industries. Duties will include supervising and programing of the promotion and sale of charcoal retorts. Salary open. Location, New York State. W8315.

CHEMICAL ENGINEERING SUPERVISOR, B.S. degree, to be responsible for production of various chemical solutions, distillation of monomers, simplified organic chemicals and standard chemical mixing procedures to obtain uniformity and quality of processes. Responsible for production schedules. Salary, $6500-$7500 a year. Location, Massachusetts. W8276.

CHEMICAL ENGINEER, recent graduate, to work in New York for a few months training. Will go to Peru, S. A. on development of an alkali project on a three-year contract. Salary, $5400 plus housing. Knowledge of Spanish helpful. P8252.

CHEMICAL ENGINEERS. (a) Junior Chemical Project Engineers, graduates, to assist in economic analysis of chemical processes; calculate material and energy balances; assist in preparation of flow sheets, etc. Salary, to $7000 a year. (b) Chemical Project Engineers, graduates, with five to eight years' experience, to perform process design engineering involving economic analysis of processes, material and energy balance calculations, preparation of flow sheets, sizing and selection of equipment for engineering and construction of heavy chemical plants. Salary, to $10,000 a year. (c) Research and Development Engineers, graduate chemical engineers, with five to eight years' experience in process development, problems. Will develop modifications of company processes and design test equipment; carry out planned research and development programs, etc. Salary, to $10,000 a year. Submit detailed resumes including current earnings and salary requirements. Company pays placement fees. Location, New York City. W8232.

CHEMISTS OR CHEMICAL ENGINEERS, graduates. (a) One for research and development work in building paper, mineral wool field, to 45; with four to five years' direct experience in building paper, mineral wool fields; knowledge of glass fibers helpful. Will do research and development of new products; customer contact to introduce new products and/or develop solutions to special problems. Salary, about $10,000 a year. Some travel. (b) One for Research and Development work on asphalt roofing and siding, with two to three years' experience in asphalt field with building materials or oil refining industry. Will work as assistant on research and development projects relating to asphalt roofing and siding. Salary, to $7000 a year. Location, New Jersey suburban area. W8230.

CHEMICAL ENGINEERS, graduates, with about seven years' experience in petroleum refining industry, with good backgrounds in petroleum refining technology and economics, for laboratory which provides technical and professional services to petroleum refiners. Location, Midwest. W8225.

San Francisco Office

PRODUCTION ENGINEER, chemical or mechanical graduate, with five to ten years' experience in phosphoric and ammo-phosphate production. Must have knowledge of process, design and operation of phosphoric and ammo-phosphates. Salary open. Location, central California. SJ-5000.

CHEMICAL ENGINEER, graduate, with four to five years' experience in propellants and explosives, with knowledge of electro-mechanical ballistic development. Must have security clearance. Will take charge of loading facilities, testing of explosive devices, load determinations, test instrumentation. Salary, $8000-$12,000 a year up, depending upon experience. Location, San Francisco Peninsula. SJ-4988.

CHEMICAL ENGINEER, graduate, with good academic record. Previous experience should include process design and plant layout work. Will start on process design, equipment layout, cost estimate studies for dust collecting system. Experience in dust collection not needed, but must be able to calculate pressure drop in ducts, calculate fan hp and volume requirements; will advance to general process work. Salary, $6000-$7200 a year depending upon experience. Apply by letter with transcript of college record. Location, San Francisco East Bay. SJ-4960.

SALES TRAINEE, graduate chemical, mechanical or electrical, either a recent graduate or with one to two years' working experience, with aptitude, desire and qualifications to enter into an industrial instrumentation sales training program involving process control and data handling instrument and equipment (temperature, pressure, flow, level), direct reading, recording, actuating or control of the electrical, mechanical, hydraulic or electronic type. For a branch office of national manufacturer. Two to six months training in Pennsylvania. Salary, $6000-$6600 a year and company car, profit sharing, expenses. San Francisco headquarters. Must be willing to accept promotional transfer to other West Coast office. SJ-4975.

TECHNICAL SUPERVISOR, graduate chemical engineer or chemist, young, qualified by academic training or experience to engage in production activities in the paper industry (print paper, foil, laminates); develop new ways, techniques, products and survey altered process, lab developments, plant production and assist sales department, provide liaison with laboratory, investigate client complaints and production controls. All at assistant level. For a manufacturer. Salary, $6840 a year to start. Location, San Francisco East Bay. SJ-4973.

PRODUCTION SUPERVISOR, graduate chemical, with from none to five years' experience, good academic background, able to supervise, with experience in this area, if experienced. Involves shift work, operating around the clock, plant production. Salary, $6000-$7200 a year depending upon experience. Apply by letter with transcript of college record. Location, San Francisco East Bay. SJ-4961.

SALES ENGINEER, chemical, electrical or mechanical graduate, 29-35, with a minimum of five years' sales or process plant experience, to provide technical assistance to clients and promote sale of instrumentation (electric, pneumatic or mechanical); provide for control, actuators, direct reading or recording instrumentation for temperature, pressure, rate of flow, etc., in process plants. For a manufacturer's district office. Salary, about $7200 a year plus company car and fringe benefits. San Francisco or Los Angeles headquarters. SJ-4920.

RESEARCH AND DEVELOPMENT ENGINEER, graduate chemical engineer or chemist, either a recent graduate or with a few years' experience, to assist head of research department in making extensive and detailed reports on all phases of sugar processing and usage. Salary, $5700 a year for a recent graduate; better salary for experienced man. Location, Sacramento Valley, Cal. SJ-4906.

GENERAL MANAGER

CHEMICAL ENGINEER—Ph.d. or M.S. in Organic Chemistry. Must have broad experience in organic chemical manufacturing—diversified. Some experience in fine chemicals, industrial intermediates and salicylates.

Broad administrative experience essential as General Manager will be responsible for all operations of the subsidiary company and development of new product lines. The parent company is an old, well established organization.

Suburban location near large Metropolitan area Northeast. High salary with excellent fringe benefits, including stock options.

BOX 5-2

CHEMICAL ENGINEERING APPOINTMENT:

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The Department of Chemical Engineering solicits applications for a staff position in a new school with a stimulating research environment.

Facilities include: new research laboratories, a one-megawatt nuclear reactor, digital computer, and an extensive stock of research instruments and devices.

Duties of the position: lecturing in transfer operations at undergraduate and graduate level, supervision of undergraduate design projects, and direction of graduate research.

Qualifications and rank: The candidate should have a doctorate in chemical engineering and experience in lecturing and in research direction. Initial appointment at the rank of associate professor is contemplated. Enquiries and the names of three references should be addressed to:

Dr. J. W. Hodgins, Chairman,
Department of Chemical Engineering,
McMaster University
Hamilton, Ontario

Chemical or Mechanical ENGINEERS

To train for production supervision, plant trouble-shooting and process engineering. Positions open at various operating locations.

Please send resume in confidence giving education, experience and approximate salary to Central Personnel Office, Solvay Process Division, Allied Chemical Corporation, P. O. Box 271, Syracuse 1, New York.

engineers

Major Company is developing an extensive diversification program calling for a wide variety of top-level talent as follows:

1. **Chemical or petroleum refining process design, project development and/or operation.**
2. **Air separation plant design and operation or related cryogenic experience.**
3. **Hydrocarbon extraction design or operation experience.**
4. **Engineering Economic evaluation.**

Prefer minimum of five years' experience applicable to any one or combination of above.

Address replies with full resume in complete confidence to: BOX 2-2

CHEMICAL ENGINEER for testing and evaluating variety of processes for manufacture of inorganic and organic chemicals. Require 10 year's broad related experience. Wood pulping helpful. Exceptional future. Salary $12,000. Pacific Northwest. Box 4-2.

ASSISTANT PLANT MANAGER. For small ultra modern food processing plant in New Orleans area. Must be graduate Chemical Engineer with minimum of three years production experience. Excellent opportunity for advancement in a new, challenging industry with a well established firm. Address replies, stating qualifications and salary requirements to P. O. Box 26398 New Orleans 26, La.

ADDITIONAL RECRUITMENT ADVERTISEMENTS

See additional display advertisements on pages 102-103.

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Baker Perkins Dbl Arm Jacketed Mixers to 300 Gal.
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1—Blaw Knox 400 gal. steel jacketed autoclave, 570# internal pressure, 85# jacket
1—Blaw Knox 45 gal. jacketed autoclave, 1500# pressure
2—Pfaudler 200 gal. glass lined reactors with impeller type agitators and drives
1—Pfaudler 50 gal. glass liner jacketed reactor complete with agitator and drive
1—Edgemoor type 316 SS 750 gal. jacketed reactor
1—Struthers Wells 500 gal. nickel jacketed reactor
1—Patterson-Kelley 6000 gal. steel jacketed reactor, 40# jacket, complete with agitator and drive
1—Patterson 2000 gal. steel jacketed reactor
2—Haveg 300 gal. pressure vessels, complete with agitators and drives
28—30,000 gal. steel vertical storage tanks

DRYERS

1—Link Belt steel roto louver dryer, Model 1003-30
3—Link Belt steel roto louver dryers, Model 207-10, 310-16, 604-20
1—Stokes Model 59DS steel rotary vacuum dryer, 5' x 30'
1—Buflovak SS rotary vacuum dryer, 3' x 15'
1—Stokes double drum dryer, 5' x 12'
1—Louisville rotary steam tube dryer, 8' x 45'
2—Louisville rotary dryers, 8' x 50', SS
1—Louisville SS rotary kiln, 30" x 28' complete
1—Louisville rotary dryer, 38" x 40', Type L
1—Traylor 4' x 40' rotary dryer
1—Rotary dryer 6' x 36'

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3—Dorrco rubber covered filters, 6' x 2'
1—Sweetland #3 stainless steel filter
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1—Niagara SS filter, Model 510-28
1—Oliver horizontal filter, 3'
1—Oliver type 316 SS precoat filter, 3' x 4'
1—Oliver SS pressure precoat filter, 5'3" x 8'
10—Shriver plate and frame filter presses, 12" x 42"
1—Shriver aluminum 30" x 30" P & F filter press, 30 chambers
1—Shriver C. I. plate and frame filter press, 36" x 36" closed deliver, 4 eye, 60 chambers
1—Shriver rubber lined filter press, 36" x 36"

CENTRIFUGES

1—Tolhurst SS 20" suspended type centrifuge with perforated basket, complete with plow and motor
1—AT&M 26" suspended type centrifuge with SS perforated basket, complete with plow and motor
1—AT&M 48" SS suspended type centrifuge, complete with plow, motor and imperforated basket
1—Bird type 316 SS centrifuge, 32" x 50"
4—Tolhurst center slung rubber covered centrifuges with perforated baskets and motors
2—Fletcher 40" center slung rubber covered centrifuges with perforated baskets and motors
1—AT&M 40" SS suspended type centrifuge complete with motor, perforated basket and plow

THE GELB GIRL—FEBRUARY 1960

MIXERS

15—Robinson type 304 SS horizontal blenders, 225 cu. ft.
3—Robinson type 316 SS sigma blade jacketed heavy duty mixer, 400 gal.
1—Baker Perkins Size 14, Type UUEM, 150 gal. jacketed double arm dispersion type mixer, complete with compression cover and 100 HP motor
1—12' x 4' pug mixer, type 316 SS
1—Patterson type 347 SS jacketed vacuum sigma kneader master, 500 gal.

MISCELLANEOUS

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1—Acme steel bubble cap column, 42" dia. with 10 trays
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1—Vulcan SS bubble cap column, 4' x 28 plates
2—Patterson Kelley steel heat exchangers, 1000 sq. ft. each
6—Struthers Wells heat exchangers, 885 sq. ft.
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50—Steel heat exchangers from 15 sq. ft. to 400 sq. ft.
9—Davis SS heat exchangers, 145 sq. ft. (NEW)
1—Struthers Wells type 316 SS heat exchanger, 330 sq. ft.
1—Condenser Service type 316 SS heat exchanger, 350 sq. ft
3—Badger type 316 SS heat exchangers, 500 sq. ft. and 600 sq. ft.
3—Robins shaker screens, SS, 3' x 6'
1—Swenson type 316 SS vacuum crystallizer, 3'6" x 12'
1—Swenson type 316 SS vacuum crystallizer, 2' x 12'
1—Blaw Knox steel distillation column, 36" x 40" with 24 trays (NEW)
3—Williams type 316 SS hammermills, Model AK
1—Swenson pilot plant spray dryer
1—Western Precipitation Corp. stainless steel spray dryer, Type N-2, Size 4-25-E
1—Sprout Waldron Model 501-D pelleter
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CHEMICAL ENGINEERING TEACHING POSITIONS AVAILABLE

A list of chemical engineering teaching positions in schools and universities in the United States and Canada on Feb. 20, 1960 may be obtained from the Secretary, A.I.Ch.E., 25 West 45th Street, New York. Salary data and rank of position are given.

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(continued from page 151)

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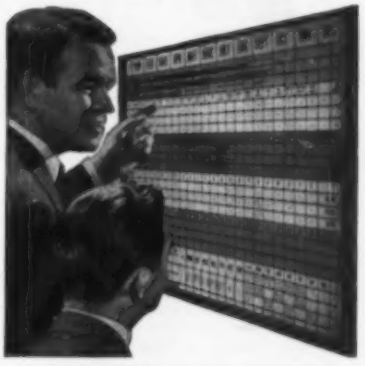

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News and Notes of A.I.Ch.E.

New chairmen—At the Fall meetings of Council one of the orders of business is careful deliberation on the chairmen of the Institute's committees. As members know, these are always reported in the Directory or the Supplement to the Directory. For those who do not request copies of this from the Secretary's office, we list here the chairmen of the Institute's committees for 1960: R. F. Shaffer, **Admissions;** W. B. Franklin, **Awards;** T. J. Walsh, **Career Guidance;** M. W. Bredekamp, **Chemical Engineering Education Projects;** H. F. Nolting, **Constitution and Bylaws;** C. C. Monrad, **Education and Accreditation;** R. L. Jacks, **Equipment Testing Procedures;** W. M. Carlson, **Machine Computation;** Irving Leibson, **Membership;** W. L. Faith, **Pollution Control Engineering;** L. S. Coonley, **Professional Development;** B. B. Kuist, **Professional Legislation;** Norman Morash, **Program;** E. R. Smoley, **Publication;** C. W. Swartout, **Public Relations;** K. H. Hachmuth, **Research;** J. J. Healy, Jr., **Sections Activities;** J. C. Lawrence, **Standards;** C. E. Huckaba, **Student Chapters;** and D. O. Myatt, **Symbols and Nomenclature.**

Membership results—South Texas, under the membership direction of H. A. Holcomb, ended this year with the largest number of new applications credited to any Local Section. The Philadelphia-Wilmington group, which has been a constant winner in the number of applications submitted every year, dropped ten behind Holcomb in South Texas in 1959. As far as results for the year are concerned, despite a bad beginning in the first part of 1959 due to the economic dip in 1958, the Institute managed to finish with as many new applications for membership in 1959 as it had for the year 1958. The last three months finished particularly strong, which made up for fewer graduates. However, we came quite a bit short of 1957, which was a record year in the Institute for total applications received.

Under the dynamic leadership of Irv Leibson, who is chairman of the Membership Committee, we expect in 1960 to better our previous records. The results for the first fifteen days encourage this hope.

Any member willing to help in membership development need only to get in touch with Irv at Humble Oil & Refining Company, Baytown, Texas, for an iron-bound contract to canvass his area.

Irv has the Membership Committee organized into an Industrial Division and an Educational Division; thus in membership work there is an active group behind the individual worker interested in expanding the membership of A.I.Ch.E., an expansion which is very necessary if the society is to maintain its position as the representative of the chemical engineering profession. The committee is composed of a representative from each Local Section who heads a local membership committee which theoretically has a membership representative for every plant, laboratory, and educational facility in the Local Section area. In addition to that, the Educational Division of the membership group has on its roster all the A.I.Ch.E. Student Chapter Counselors in the country, headed by Joe Koffolt, who for years has held a record in that every member of his senior class has voluntarily applied for A.I.Ch.E. membership upon graduation.

There is a membership manual, and Irv will send it to any member who wants to know more about A.I.Ch.E.'s membership activities. He is asking each member of A.I.Ch.E. to help achieve a record year in 1960.

A kudo—The Secretary has known for many years that the chemical engineers on convention are desirable house guests for any hotel; however, it is not very often that we have direct confirmation of this from outside

sources. Joel Henry, Assistant Secretary, who is in charge of meetings, received from the Sheraton-Palace in San Francisco the information that the "American Institute of Chemical Engineers was by far one of the neatest and most congenial groups" that the hotel has ever had.

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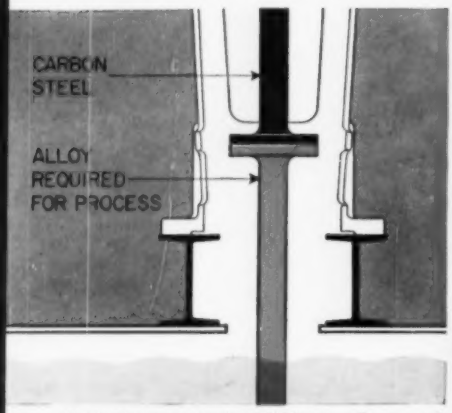

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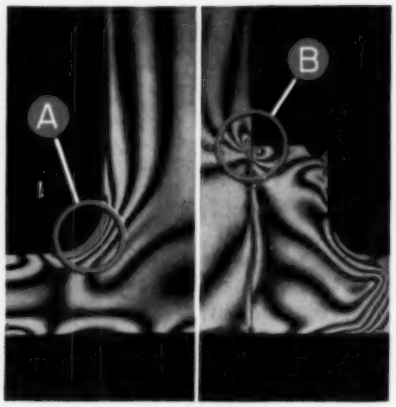

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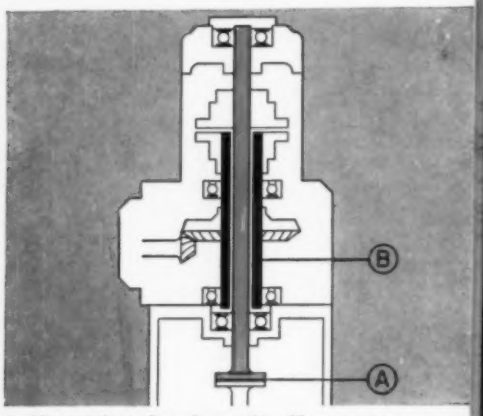

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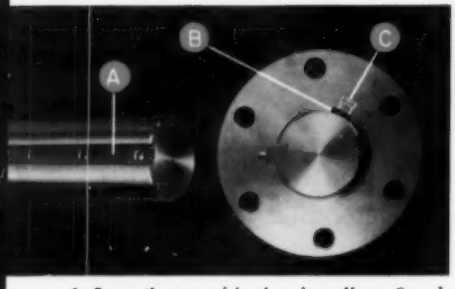

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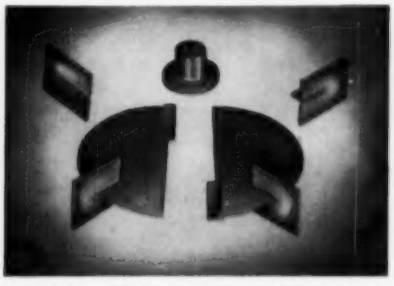

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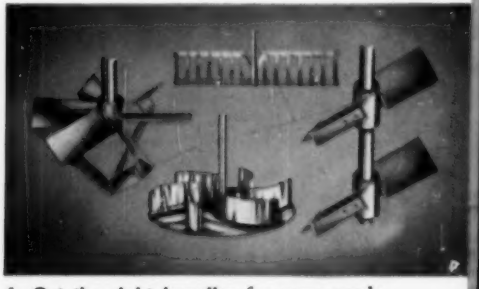

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